

**Current and Sea-Level Measurements in the
Northwest Passage
Volume 2, March 1983 - April 1984.**

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1987

**Canadian Data Report of
Hydrography and Ocean Sciences
No. 51**



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Canadian Data Report Of Hydrography and Ocean Sciences

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Les établissements des Sciences et Levés océaniques dans les régions et à l'administration centrale ont cessé de publier leurs diverses séries de rapports depuis décembre 1981. Vous trouverez dans l'index des publications du volume 38 du *Journal canadien des sciences halieutiques et aquatiques*, la liste de ces publications ainsi que le dernier numéro paru dans chaque catégorie. La nouvelle série a commencé avec la publication du Rapport n° 1 en janvier 1982.

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CURRENT AND SEA-LEVEL MEASUREMENTS IN THE NORTHWEST PASSAGE
VOLUME 2, MARCH 1983 - APRIL 1984.

by

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PREFACE

This report is the second of three data reports documenting current and sea-level measurements in the Northwest Passage of the Canadian Arctic Archipelago between March 1982 and April 1985. Each report deals with the activities undertaken during a year-long period. Analysis and interpretation of these data appear in two separate technical report.

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Cat. No. Fs 97-16/51

ISSN 0711-6721

Correct citation for this publication:

Buckingham, W.R., R.A. Lake, and H. Melling. 1987. Current and Sea-Level Measurements in the Northwest Passage. Volume 2, March 1983 - April 1984. Can. Data Rep. Hydrogr. Ocean Sci. No. 51:84pp.

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ABSTRACT

Buckingham, W.R., R.A. Lake, and H. Melling, 1987. Current and Sea-Level Measurements in the Northwest Passage. Vol. 2, March 1983 - April 1984. Can. Data Rep. Hydrogr. Ocean Sci. No. 51:84 pp.

A three-year program of current and sea-level measurements was undertaken between March 1982 and April 1985 in the Canadian Arctic Archipelago by the Institute of Ocean Sciences of the Department of Fisheries and Oceans. The measurements were in the form of time series, at fixed depths by self-recording instrument packages, of temperature, salinity, current speed, current direction and water pressure at the seafloor. The activities during each year of the study concentrated on a specific region of the Northwest Passage within the Archipelago. The emphasis in 1982 was on the western portion (M'Clure Strait, Prince of Wales Strait, and Viscount Melville Sound), in 1983 on the central portion (eastern Viscount Melville Sound and Barrow Strait), and in 1984 on the eastern portion (Barrow Strait and adjacent channels). This report discusses the aims of the project, the logistics of the 1983 field work, and summarizes the data acquired during that year in tabular and graphic form.

key words: Arctic Archipelago, Northwest Passage, temperature, salinity, current, tide.

RESUME

Buckingham, W.R., R.A. Lake, and H. Melling, 1987. Current and Sea-Level Measurements in the Northwest Passage, Vol. 2, March 1983 - April 1984. Can. Data Rep. Hydrogr. Ocean Sci. No. 51:84 pp.

De mars 1982 à avril 1985, l'Institut des Sciences de la Mer du MPO a réalisé un programme triennal de mesures du niveau de la mer et des courants dans l'archipel arctique canadien. Ces mesures ont été prises sous forme de séries chronologiques, à des profondeurs déterminées, par des groupes d'instruments automatisés, de la température, de la salinité, de la vitesse et direction de courant et de la pression de l'eau au fond de la mer. Les activités annuelles ont porté sur une région déterminée du passage du Nord-Ouest de l'archipel. En 1982, l'accent a été mis sur la partie ouest (détroit de M'Clure, détroit de Prince-de-Galles, et détroit du Vicomte-Melville), sur la partie centrale en 1983 (partie est du détroit du Vicomte-Melville et détroit de Barrow), et en 1984, sur la partie est (détroit de Barrow et chenaux adjacents). Le présent rapport porte sur les buts du projet, le soutien logistique du travail sur le terrain en 1983 et résume les données recueillies cette année-là, qui sont présentées sous forme de tableaux et de graphiques.

Mots-clés: archipel arctique, passage du Nord-Ouest, température, salinité, courant, marée.

ACKNOWLEDGEMENTS

The authors wish to thank various members of the Institute of Ocean Sciences whose diligent efforts helped to make this project a success. In particular we thank electronics technician P. Johnston, support technicians S. Moorhouse and G. Moonie, and J.W. Green from the computing section. Logistic support, and accommodation at Resolute Bay was provided by the Polar Continental Shelf Project of the Department of Energy, Mines and Resources. Meals, radio and accommodations were also made available at Rae Point by Panarctic Oils, Ltd. We sincerely thank both organizations, and the particular individuals involved, for their cooperation and assistance. The loan of the tethered submersible DART, with its skilled operator Steve Taylor, by the Defence Research Establishment - Pacific, is greatly appreciated.

The funding for this project was provided by the Marine Transportation Research and Development Programme.

1. INTRODUCTION

A three-year physical-oceanographic study was undertaken between 1982 and 1985 in the Canadian Arctic Archipelago, centering on the complex of waterways known as the Northwest Passage. The study was carried out by the Department of Fisheries and Oceans at the Institute of Ocean Sciences (IOS). It extended from Amundsen Gulf in the west, through Prince of Wales Strait, M'Clure Strait, Viscount Melville Sound, Barrow Strait, and Lancaster Sound to Baffin Bay in the east (see Figure 1). The study also included the various passageways and basins bordering the Northwest Passage. The overall objective included the following goals:

- 1) the identification of the magnitude and direction of tidal and non-tidal currents,
- 2) the description of tidal propagation,
- 3) the identification of sources and destinations of various water-masses,
- 4) the identification of the relative importance of physical forces which determine currents and water-mass distribution (e.g. tidal forces, baroclinic forces related to horizontally inhomogeneous distribution of water density and non-tidal barotropic forces related to oceanic and atmospheric circulation),
- 5) the identification of temporal and spatial variability in current and water-mass distribution. Periods of particular importance are tidal (semi-diurnal and diurnal), seasonal, and interannual. Also of potential importance are singular or non-periodic events such as storm surges,
- 6) the estimation, to an order of magnitude, of the volume of water transport into and out of the study area and the partition of that transport.

The activities during each year of the study concentrated on a specific region of the Northwest Passage. The emphasis in 1983 was on eastern Viscount Melville Sound and adjacent passages. The field operations were undertaken during the early spring months, at which time the solid ice-cover made a stable platform from which to work.

This report describes the acquisition of water-current and sea-level information in 1983/84 as time series of current, temperature, salinity and sea-floor pressure and presents the data in final processed form. The main study area comprised the eastern end of Viscount Melville Sound, the western part of Barrow Strait, Austin Channel, Byam Martin Channel and northern M'Clintock Channel. The relevant mooring locations are indicated by the square symbols in Figure 2 and the tide gauges are indicated by circular symbols. Tide gauges operated by other agencies are shown as diamond symbols. Data reports covering the activities during 1982 and 1984 may be found in Volumes 1 and 3 of this report series.

Relevant ocean measurements were acquired concurrently by the Canadian Hydrographic Service in Prince Regent Inlet (CHS-Central: seafloor pressures) and by the Bayfield Laboratory for Marine Science and Surveys in Barrow Strait (DFO-Central: seafloor pressures and current). The Canadian Hydrographic Service maintain, tide stations at Cape Parry and Resolute Bay, and in 1983/84 maintained stations at Mould Bay, Isachsen and Auldhild Bay. Most of these moorings are indicated by star symbols in Figure 2.

The study area has not previously been extensively investigated due to its remoteness and to the difficulty of ship operations. The sea surface is completely frozen during most of the year, and is often ice-choked during the



Figure 1. A map of the Canadian Arctic Archipelago. The Northwest Passage shipping route will likely be through Lancaster Sound, Barrow Strait, Viscount Melville Sound, and Prince of Wales Strait.

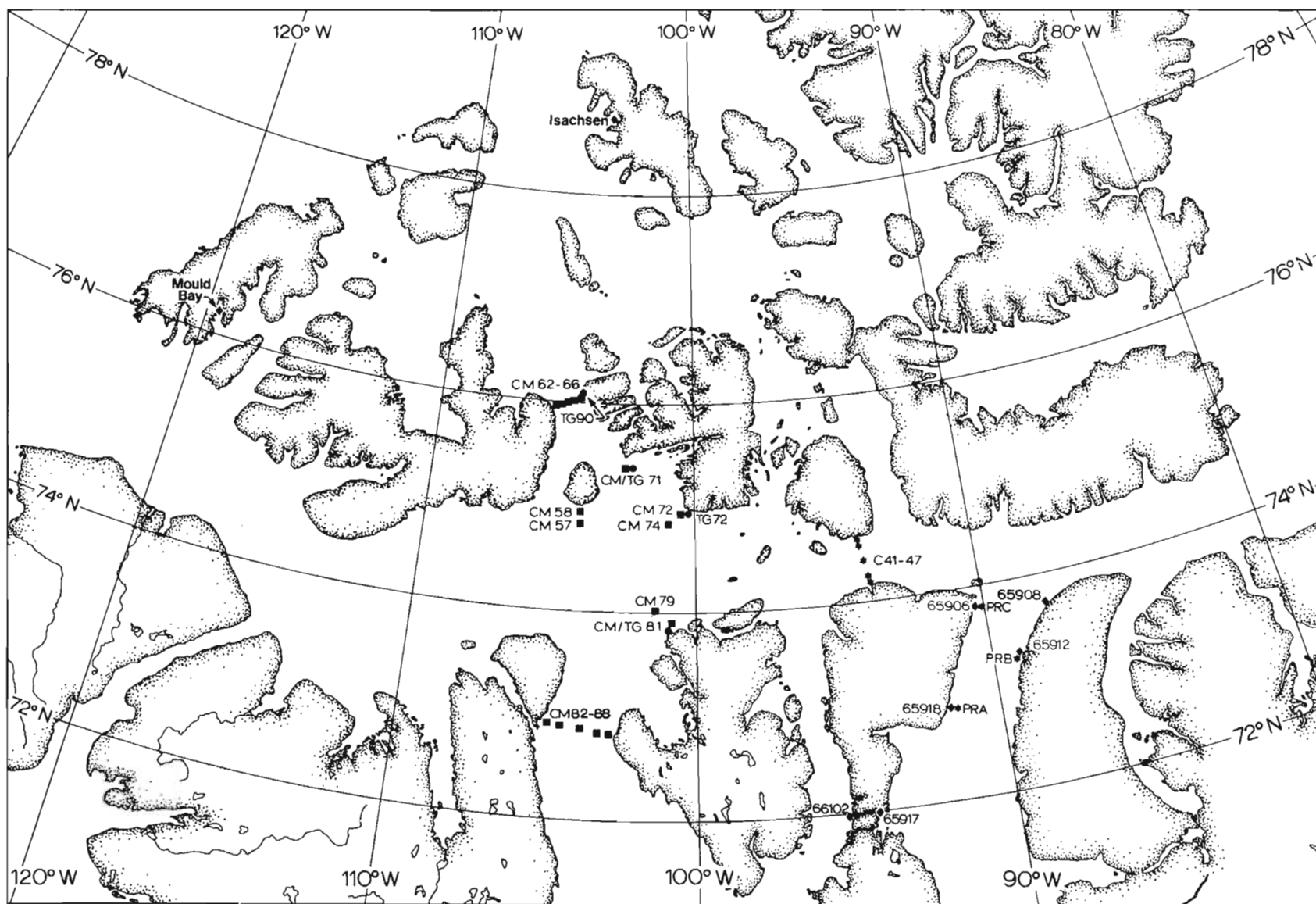


Figure 2. Location of recording instrumentation moorings throughout the Arctic Archipelago in 1983 (squares - current meters; dots - tide gauges; stars and diamonds - current meters and tide gauges from concurrent studies by other agencies.)

short navigation period. Previous oceanographic research in the Arctic Archipelago has been tabulated by Fissel, Knight and Birch (1984). The earliest significant collection of oceanographic data was accomplished from ships in summer during the 1950's and 1960's. These data were sufficient to delineate the regional water-mass characteristics. In 1976 and 1977 direct current measurements were made in Byam and Austic Channels and Crozier and Pullen Straits by the Institute of Ocean Sciences. In 1977 and 1978 investigators from the Physical Oceanographic Group of the Canada Centre for Inland Waters completed a number of current meter transects across Viscount Melville Sound, Prince of Wales Strait, and adjacent channels (Peck, 1978 and Prinsenberg, 1978). Current data across the western end of Viscount Melville Sound were gathered in 1979 as part of the Polargas Project (1979). A number of tidal height measurements were made during 1979 and 1980 as part of the Bridport Inlet studies by IOS. The Canadian Hydrographic Service also made extensive tidal height measurements in 1977, and an additional tidal height record was obtained as a part of the Polargas program in 1979.

The present study involved measurements by CTD probe, recording current meters, tide gauges, and meteorological stations. This report deals with the recording instrument measurements. Section 2 describes the physical setting and bathymetry of the study area and the mooring locations during 1983/1984. Section 3 recounts the logistics, equipment used, and the timing of the measurements, while Section 4 deals with the data processing procedures. The data are presented as time-series plots in the Appendix.

2. PHYSICAL SETTING AND STATION LOCATIONS

2.1 Arctic Archipelago

The Canadian Arctic Archipelago consists of a large group of islands lying on the extensive polar continental shelf of North America (Figure 1). The Archipelago extends roughly 1500 kilometers between the 68° and 82° North latitude and about 2700 kilometers between 60° and 130° West longitude (at 70° North). These islands are bounded to the north and west by the Arctic Ocean and the Beaufort Sea respectively, to the south by the mainland of the North American continent and to the east and southeast by Nares Strait, Baffin Bay, Davis Strait, and Labrador Sea. For convenience, the Archipelago is often divided into three sections from north to south as follows: the Sverdrup Basin lying within the Queen Elizabeth islands (i.e., all islands north of Parry Channel); Parry Channel, consisting of M'Clure Strait, Viscount Melville Sound, Barrow Strait, and Lancaster Sound; and the "Southern Channels" comprising Amundsen Gulf, M'Clintock Channel, the Gulf of Boothia, and other, lesser waterways.

2.2 General Bathymetry

The channels and basins throughout the Archipelago are in general substantially shallower than the major adjoining oceanic basins. The continental shelf effectively limits free passage of water to maximum depths of about 450 meters into Sverdrup Basin, to about 380 metres into M'Clure Strait, and to about 360 meters into Amundsen Gulf. To the east, Baffin Bay has depths up to 2300 meters, but the sill in Davis Strait (to the south of Baffin Bay) limits deep water exchange with the North Atlantic to depths of less than 700 meters. Another shallow entrance (50 meters) to the Archipelago from the North Atlantic exists through Hudson Strait, Foxe Basin, and Fury and Hecla

Strait in the south. The deepest continuous passage through the Archipelago exists through Parry Channel and has a limiting sill of 125 meters in Barrow Strait. The passageways connecting Sverdrup Basin to the southern channels (M'Clure Strait, Viscount Melville Sound, Barrow Strait, etc.) are in general constricted by shallow sills on the order of 100 meters in depth. South of Parry Channel depths are characteristically shallow (mostly less than 200 meters) with the exception of some deeper areas of greater than 400 meters extending into Prince Regent Inlet from Lancaster Sound.

2.3 Mooring Locations and Local Bathymetry

The Northwest Passage field study in 1983 was concentrated on the eastern end of Viscount Melville Sound. The study area was bounded on the north by Melville Island, Byam Martin Channel and Bathurst Island, on the east by the 100° West meridian (approximately), on the south by Stefansson Island, M'Clintock Channel and Prince of Wales Island, and on the west by the 106° W meridian. Due to the large size of the area studied (about 50,000 square kilometres) only near-surface currents were measured systematically over the area, and even for the surface-measurement arrays, mooring spacing was substantially greater than internal deformational and topographic scales of variability. In anticipation of shoreline "hugging" baroclinic flows, meters were more closely spaced near shores. Two complete transects were instrumented across Byam Martin Channel and M'Clintock Channel and partial transects were instrumented at channel junctions near Capes Gillman, Cockburn and Berkeley (see Figure 2). Recording pressure gauges were deployed at Capes Aldrich, Cockburn and Berkeley, and at the base of the mooring in central Austin Channel. Vertical variation of current was measured at one location in central Austin Channel.

Concurrent measurements of current and seafloor pressure were acquired by the Canadian Hydrographic Service in Prince Regent Inlet and by the Bayfield Laboratory for Marine Science and Surveys in Barrow Strait. Farther afield the Canadian Hydrographic Service made sea-floor pressure measurements at Mould Bay, Isaachsen, Auldild Bay and Pond Inlet, in addition to continuing longterm measurements at Cape Parry, Alert and Resolute Bay. These locations are plotted, where possible, in Figure 2.

Instrument location, depth, type, serial number, recovery success and observational period are tabulated for this program, and for concurrent studies, in Table 1.

The bathymetry of the channels in the vicinity of the instrument moorings is shown in Figure 3. Figure 3 shows the bathymetry of the western boundary to be smoothly sloping from the north and the south, with the deepest point (about 500 m) occurring at about one third of the width from the south shore. The square and triangular symbols of this figure denote 1982 and 1983 moorings respectively. From this point to the eastern boundary the seafloor shoals and flattens, so that along 100° W, all depths are less than about 150 m. To the south, a sill of about 270 m depth walls a deeper basin in M'Clintock Channel, while to the north, complex bathymetry between 100 and 250 m depth extends to deeper waters northwest of Byam Martin Channel. Two significant obstructions in this area are Byam Martin Island, and Keene Bank, which shoals to depths near 7 m at 75.2° N 102° W.

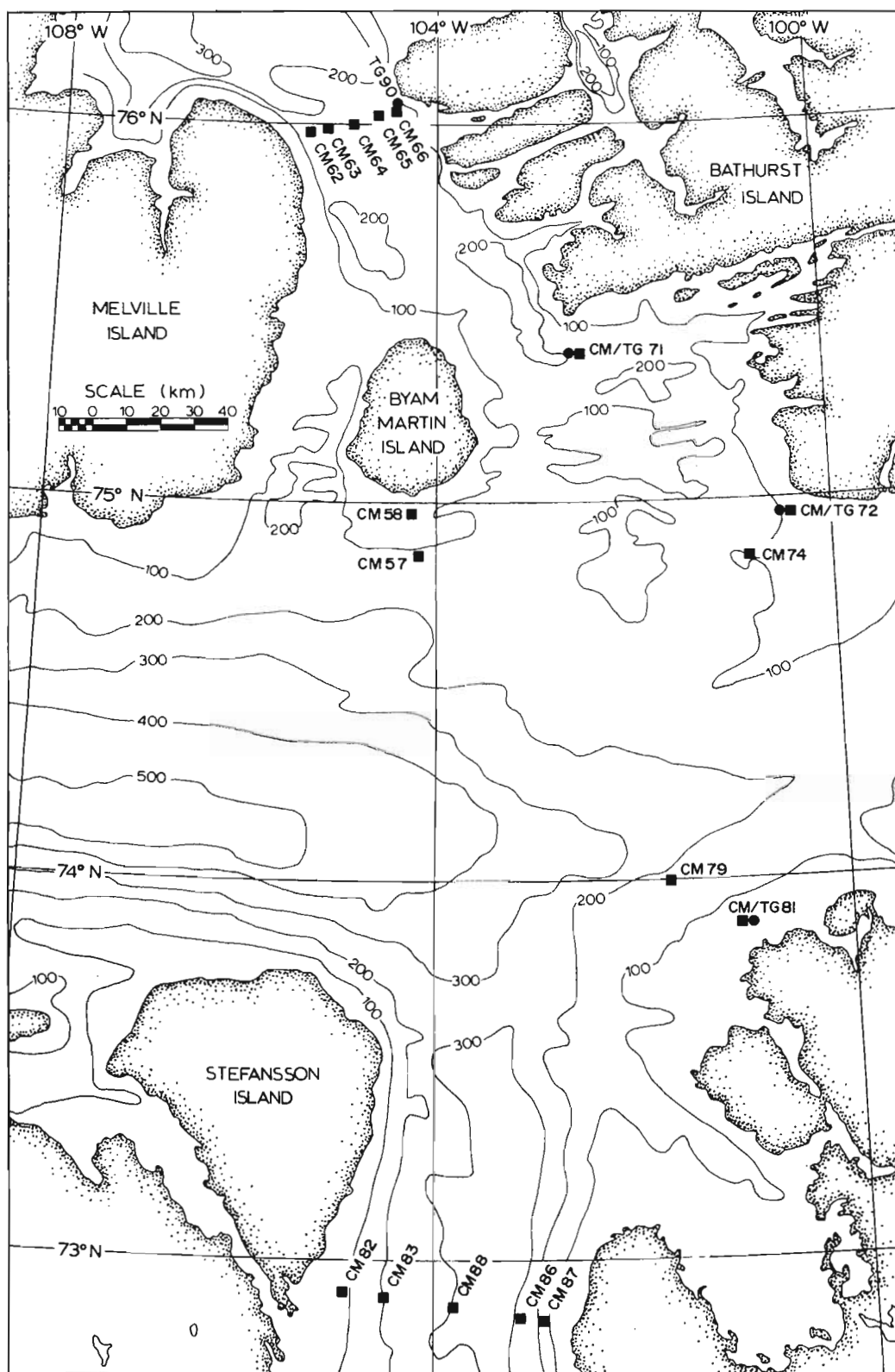


Figure 3. Bathymetry of the eastern part of Viscount Melville Sound, M'Clintock Channel, and Byam Martin Channel (squares - current meters; dots - tide gauges.)

In the following table, CCIW = Canada Centre for Inland Waters,
T and C = Tides and Currents Section of Department of Fisheries
and Oceans, CHS = Canadian Hydrographic Service.

Table 1. Summary of Recording Instrument Records

| Region | Site | S/N | Latitude | Longitude | Type | 3 mos. | 12 mos. | Depth (m) | Data Recovery/ Remarks |
|-----------------------|------|------|----------|-----------|------|-----------|------------|--------------|---------------------------------|
| Byam Martin Island | CM57 | 1939 | 74°51.6' | 104°12.8' | RCM | ✓ | | 18 | ✓ |
| | CM58 | 1936 | 74°59.1' | 104°13.4' | RCM | ✓ | | 18 | ✓ |
| Byam Martin | CM62 | 3223 | 75°55.6' | 105°22.6' | RCM | ✓ | | 18 | ✓ |
| " | CM63 | 3278 | 75°58.1' | 105°10.6' | RCM | ✓ | | 18 | ✓ |
| " | CM64 | 3228 | 76°00.5' | 104°54.6' | RCM | ✓ | | 18 | x instr. malf'n. |
| " | CM65 | 3387 | 76°02.9' | 104°38.8' | RCM | ✓ | | 18 | ✓ |
| " | CM66 | 3388 | 76°04.6' | 104°27.9' | RCM | ✓ | | 18 | ✓ |
| Austin Channel | CM71 | 3395 | 75°23.3' | 102°38.6' | RCM | ✓ | | 18 | ✓ |
| " | CM71 | 2466 | | | RCM | | ✓ | 73 | ✓ |
| " | CM71 | 2470 | | | RCM | | ✓ | 123 | ✓ 1 change in ref. direction |
| Cape Cockburn | CM72 | 2467 | 74°57.1' | 100°26.9' | RCM | ✓ | | 18 | ✓ |
| " | CM74 | 1932 | 74°51.0' | 100°49.7' | RCM | ✓ | | 18 | ✓ |
| Cape Berkeley | CM79 | 1931 | 74°00.2' | 101°39.8' | RCM | ✓ | | 18 | ✓ |
| " | CM81 | 5361 | 73°52.9' | 100°59.7' | RCM | ✓ | | 18 | ✓ |
| M'Clintock Channel | CM82 | 1930 | 72°56.3' | 104°52.0' | RCM | ✓ | | 18 | ✓ |
| " | CM83 | 5456 | 72°54.8' | 104°29.0' | RCM | ✓ | | 18 | ✓ |
| " | CM86 | 5474 | 72°51.9' | 103°08.6' | RCM | ✓ | | 18 | ✓ |
| " | CM87 | 0972 | 72°50.5' | 102°54.1' | RCM | ✓ | | 18 | ✓ |
| " | CM88 | 1929 | 72°52.7' | 103°46.2' | RCM | ✓ | | 18 | x lost |

Table 1. Summary of Recording Instrument Records (continued)

| Region | Site | S/N | Latitude | Longitude | Type | 3 mos. | 12 mos. | Depth (m) | Data Recovery/ Remarks |
|------------------------|------|------|----------|-----------|-------|-----------|------------|---------------------|---|
| Barrow Strait | C41 | | 74°36.2' | 94°02.8' | RCM | ✓ | | 10 | ✓ CCIW |
| " | C42A | | 74°34.0' | 94°01.1' | RCM | ✓ | | 10,40, 60,80,120 | ✓ CCIW |
| " | C44 | | 74°24.1' | 93°54.7' | RCM | ✓ | | 10 | ✓ CCIW |
| " | C46A | | 74°13.3' | 93°38.3' | RCM | ✓ | | 10,40, 60,80,120 | ✓ CCIW |
| " | C47 | | 74°11.7' | 93°35.3' | RCM | ✓ | | 10 | ✓ CCIW |
| " | C42B | | 74°34.0' | 94°01.1' | RCM | | ✓ | 40,80,110 | x CCIW, lost |
| " | C46B | | 74°13.3' | 93°38.3' | RCM | | ✓ | 40,80,110 | x CCIW, lost |
| Austin Channel | CM71 | 0301 | 75°23.3' | 102°38.6' | TG4 | | ✓ | 173 | x P _{max} = 270 dbar; instr. malf'n. |
| Cape Cockburn | TG72 | 0366 | 74°57.1' | 100°26.9' | TG5A | ✓ | | 76 | ✓ P _{max} = 270 dbar |
| Cape Berkeley | TG81 | 0367 | 73°52.9' | 100°59.7' | TG5A | ✓ | | | x lost |
| Byam Martin Channel | TG90 | 0080 | 76°05.5' | 104°25.5' | WLR5A | ✓ | | 110 | ✓ P _{max} = 270 dbar |
| Barrow Strait | C42A | | 74°34.0' | 94°01.1' | TG | ✓ | | 129 | ✓ CCIW |
| " | C44 | | 74°24.1' | 93°54.7' | TG | ✓ | | 158 | ✓ CCIW |
| " | C46 | | 74°13.3' | 93°38.3' | TG | ✓ | | 162 | ✓ CCIW |
| Auldchild Bay | | | | | TG | | ✓ | | ✓ CHS |
| Isachsen | | | | | TG | | ✓ | | ✓ CHS |

3. DATA COLLECTION

3.1 Instrumentation

In total, 19 recording current meters and 4 recording pressure gauges were deployed in March and April 1983 within the study area delineated in Section 2.3. Of the current meters, 17 were suspended from the ice for a deployment of between one and three months at shallow depth (~20 m). These meters were Aanderaa Instruments, Ltd. RCM4's, modified at the Institute of Ocean Sciences to the 'vane-follower' configuration described below. The remaining 2 current meters were also Aanderaa RCM4's in the 'vane-follower' configuration, and were used on the 12-month deployment in Austin Channel, where stable ice for suspension could not be expected throughout the deployment. A Mesotech acoustic release (Model 501AR) was used to secure the subsurface mooring in Austin Channel. Recording pressure gauges were manufactured by Aanderaa Instruments, Ltd. (models, as noted in Table 1: TG4A, WLR5A). All gauges use the Paroscientific, Inc. Digiquartz pressure transducer, with full-scale pressure ranges as indicated in Table 1.

Special modification to the RCM4's was as follows: Two or more of the resistors in each of the bridge circuits for temperature and conductivity ratio were exchanged for values yielding 10-bit resolutions of about 0.005°C and 0.00016 respectively, and ranges centred on those of interest. For temperature this range was typically (-2.5°C, +2.5°) and for salinity approximately (29, 35). Resolution in salinity was about 0.006. Aanderaa current meters were deployed in lengthened pressure cases which permit the installation of two batteries, desirable for long records at low water temperature. In the 'vane follower' configuration, a small (8.7 cm high by 5.8 cm wide) vane was suspended beneath the pressure case in mounts held by 3 stainless steel rods about 6 mm in diameter. The vane was neutrally buoyant in seawater. The field from two magnets mounted above the vane and free to turn with it was adequate to orientate the compass within the case. In this way current direction relative to the case was measured, while geographic orientation of the case was established at deployment and maintained until recovery.

Three methods were used for positioning moorings. Pressure gauge moorings nearshore were sited by sextant relative to natural landmarks, or to markers set up for the purpose. Moorings more than a few hundred meters from shore were positioned using a GNS-500A VLF/Omega navigation system installed on the deploying aircraft and initialized at nearby geodetic survey points. This allowed positioning to within a 500 m radius. The bottom-founded mooring in Austin Channel was positioned to an accuracy of a few meters using microwave transponders (a Del Norte system) deployed at known locations for this purpose. Sites where moorings were to be recovered before the break-up of fast ice in summer were marked by 4-foot square by 1-foot high aluminum marker boxes painted red, and by radio beacons operating at 130 MHz (Novatech Designs Ltd., Model RF200). Sites where moorings were to be recovered one year later were marked by underwater acoustic beacons operating at 37 kHz (Johnson Laboratories, Inc., Model JL1).

3.2 Mooring Design, Deployment and Recovery

'Vane-follower' current meters were suspended from the sea ice on 1-inch hydraulic hose (see Figure 4). The hose was chosen because of its high torsional rigidity despite reasonable bending flexibility. Resistance to twisting

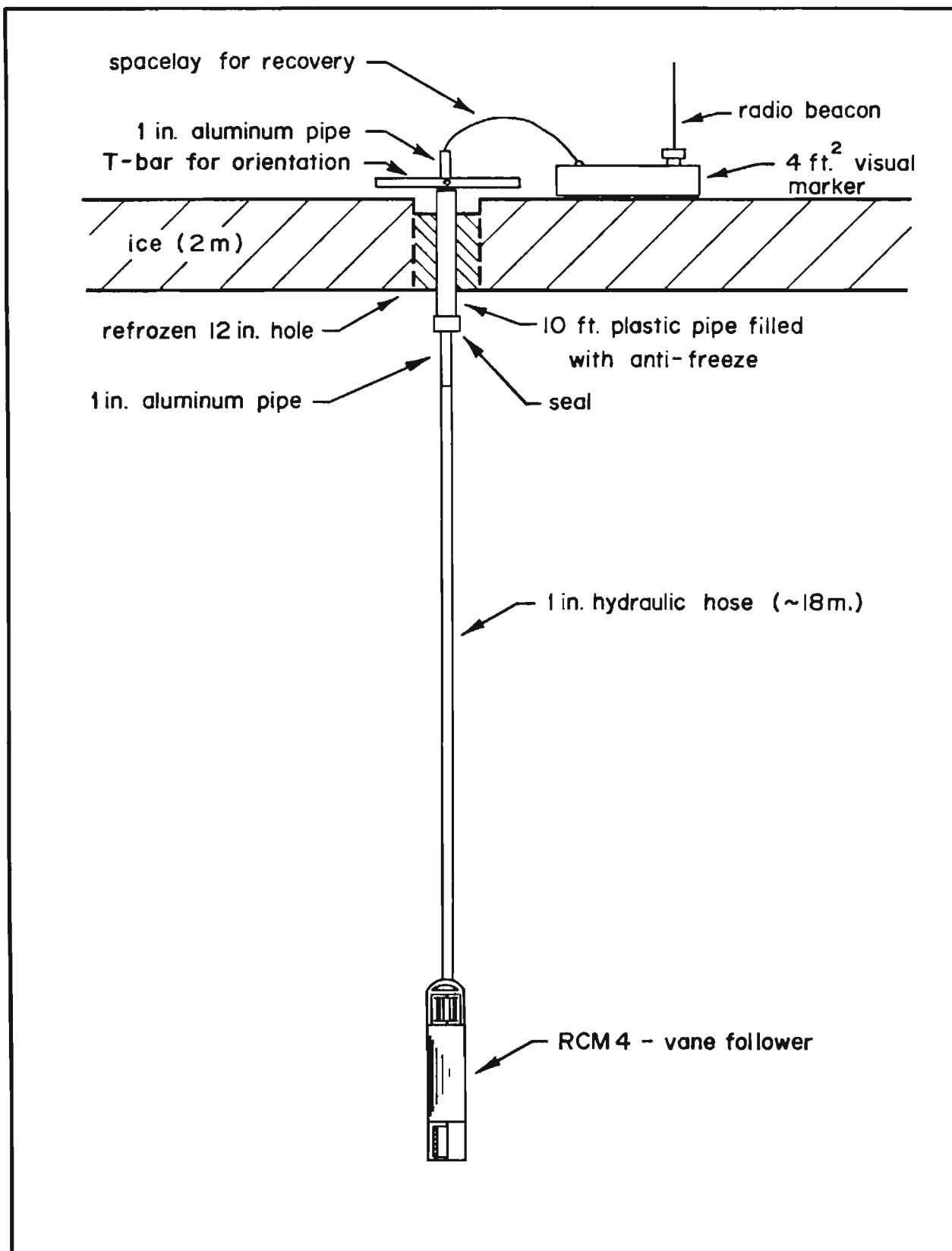


Figure 4. Vane-follower current meters suspended from the sea-ice on hydraulic hose.

was essential for maintaining a direction reference for current measurement. Meter depth was 18.5 m below the upper ice surface for all near-surface instruments. The hose was terminated and bolted to a 1-inch aluminum pipe just below the ice. This 12-foot pipe, and a vinyl-coated cable within it passed through the ice inside a 10-foot pipe of polyvinyl chloride plastic (PVC). A rubber seal between the metal and PVC pipes at the lower end of the latter permitted the space between the pipes to be filled with a 50/50 ethylene glycol/water solution. A crossbar at the top of the metal pipe held the weight of the mooring and allowed mooring orientation (and that of the current meter) to be established. The assembly was deployed through an 8-inch-diameter hole augered in the ice and allowed to freeze in. The plastic-coated cable was crimped to the square site marker as a security measure. At the time of recovery, an 8-inch hole was augered beside the mooring and the crossbar on the mooring removed. The metal pipe was then lowered on the cable until well clear of the ice. At this point, the cable was hooked by a pole manipulated through the adjacent hole and the assembly pulled through this hole to the surface. The PVC pipe (still frozen in the ice) was abandoned. Simulation of the mooring response to flow using the model of Bell (1979) indicated that the vertical displacement of the current meter was only 0.2 m with a 50 cm/s current.

Current meters in "vane follower" configuration were used at site CM71 in Austin Channel on the bottom-founded mooring (see Figure 5). Flotation was provided by a single 28" diameter steel float (Ocean Research Inc., Model SS28). The principal mooring "line" was assembled on site from aluminum tubing (10-foot lengths) of 1" diameter. Current meters were mounted in load-bearing frames made from two 1/2"-diameter stainless steel rods spread to a separation of 8" to allow inclusion of the RCM4. Frames were about 4 feet in length, and were bolted in line with the tubing. The anchor consisted of steel chain lengths contained in a 45-gallon oil drum with a harness of steel flat stock to reinforce it. Steel feet penetrated the sediment to minimize anchor movement. The mooring was attached to the anchor via a universal joint from an automobile which permitted bending in any plane, but no twisting. The overall intent of the design was to achieve a high degree of torsional rigidity while allowing bending. Magnetic compasses could not be used at this site due to the weak horizontal geomagnetic field. Orientation of the mooring was determined after deployment. A single acoustic transponding release was used on the mooring. Current meters were positioned at depths of 73 m and 123 m. Pressure records from the uppermost RCM4 indicated negligible (<1 m) fluctuations in meter depth in response to current drag on the mooring. The deployment winch, quadripod, ice-hole melter and other mooring gear were designed and built at the Institute of Ocean Sciences to meet the requirements of the task, and yet be aircraft transportable.

Recording pressure gauges were moored in two ways. Those gauges required for tidal description, and short-term (1-3 month) deployment were strapped above a steel or lead ballast weight and lowered to upright position on the seafloor (see Figure 6). Sufficient slack was left in the polypropylene rope to accommodate sea-level variations, and the rope was secured to the marker box on the ice. For recovery, a hole was augered in the ice adjacent to the in-frozen rope, the rope hooked and the instrument raised from the seafloor. For the gauge moored in Austin Channel over 12 months, a cradle was welded to the anchor bucket of the RCM mooring. A slack line connected the mooring to the gauge in order that the mooring, when released, would also raise the gauge to the surface.

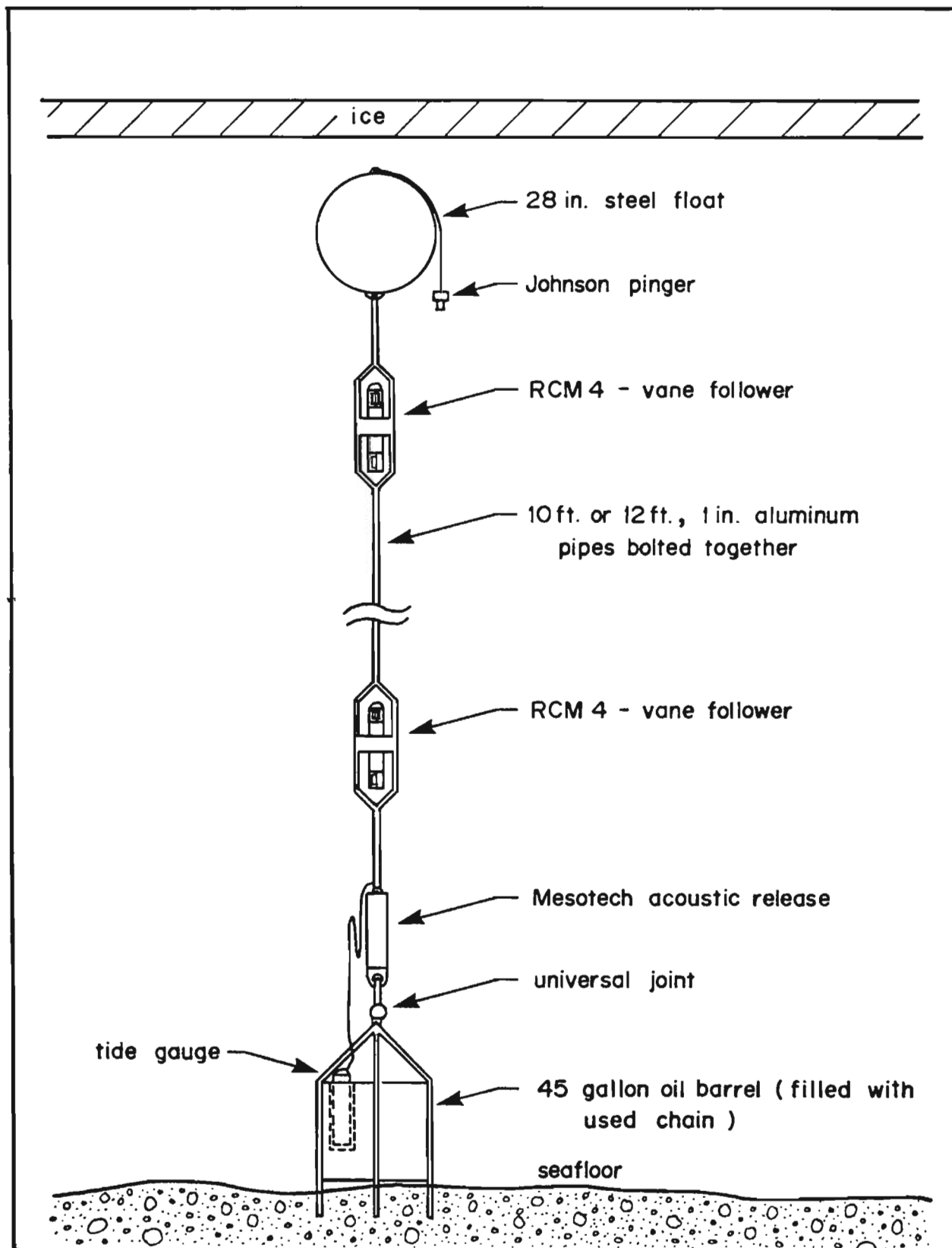


Figure 5. Bottom-founded mooring with vane-follower current meters.

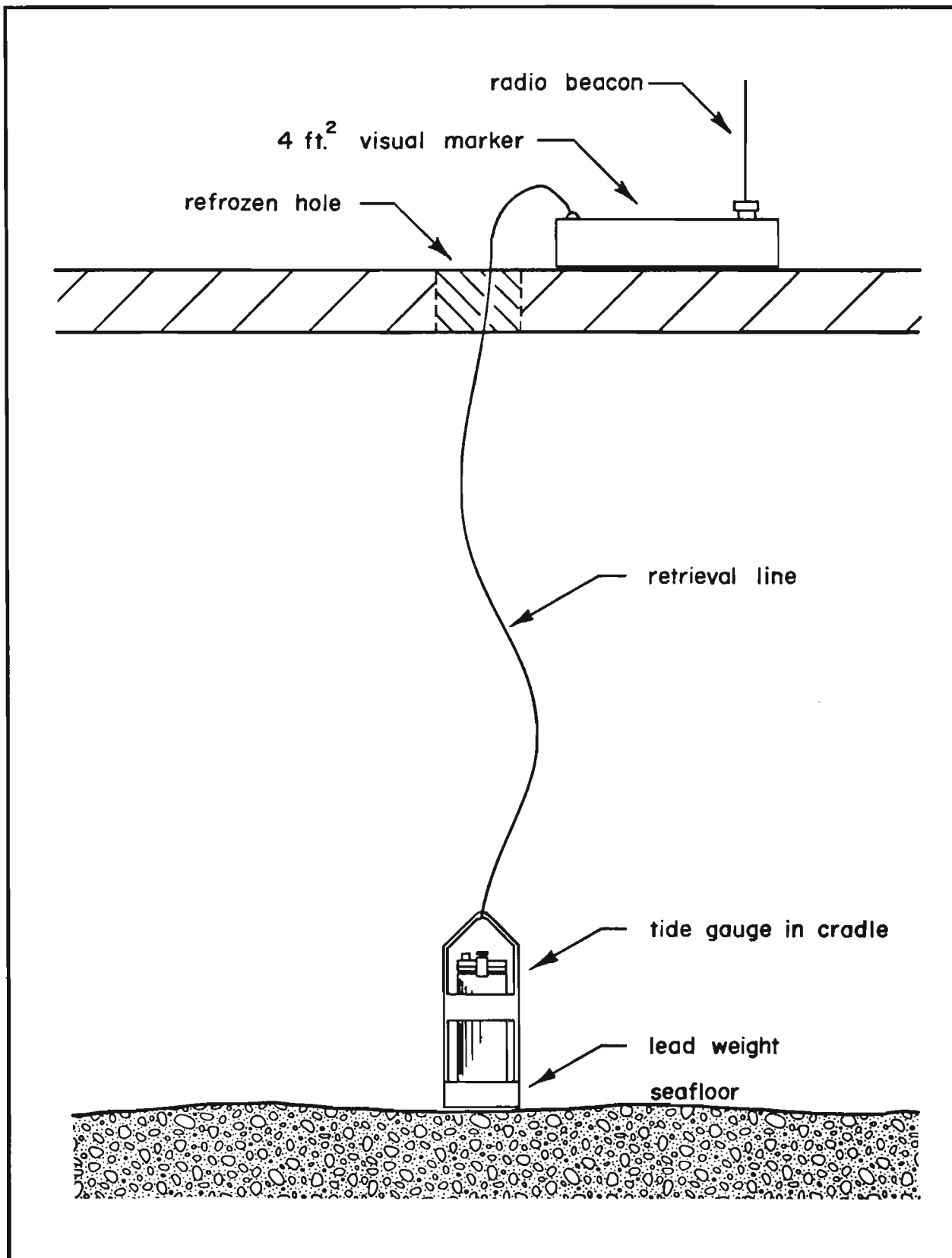


Figure 6. Mooring for short-term tide gauge deployment.

Mooring operations were conducted during the first week of April 1983. Activity was supported from the Panarctic Oils Ltd. supply base at Rae Point. Most operations were carried out from a chartered Bell 206L-1 helicopter, while caches of fuel and equipment were established in the working areas by deHavilland DHC-6 Twin Otter on ski/wheel gear.

Recovery of ice-secured instruments was accomplished between 22-23 May and 10-11 June 1983, using a Bell 205 helicopter. Two instruments were not recovered. An RCM at site CM88 in M'Clintock Channel was abandoned on account of poor visibility and a non-functional VHF beacon, while the tide-gauge installation at Cape Berkeley had been damaged by bears and the tether line could not be located.

Retrieval of bottom-mounted instruments was attempted in late April 1984 using a Twin Otter for transport. The mooring at CM71 was easily located, but the release failed to function because the drive motor operating the hook remained stalled. A tethered submersible, the Dart (International Submarine Engineering, Ltd., Vancouver) was borrowed from a Department of National Defense (DREP) camp about 200 miles distant and flown to the site. The operator was able to locate the anchor clump of the mooring at 175 m depth using sonar and a video camera on the submersible, and to attach a line to the float at 70 m depth. The mooring, including its anchor, was then winched to the surface, and the instruments recovered in the normal fashion.

The timing of successful operational periods of the recording instrumentation is shown in the bar chart of Figure 7.

3.3 Calibration

Current meters were deployed with sensors for current speed, direction, water temperature and conductivity. The speed sensors were not calibrated for this deployment, since experience has shown the calibration to be stable provided that rotor bearings are well maintained. Rotor thresholds were verified to be within tolerance by testing for rotation in response to a minimum torque specified by Aanderaa Instruments. It should be noted that in the 'vane follower' configuration, flow may approach the meter from any direction. (In the standard configuration flow is always at right angles to the rotor support yoke). It has recently been established (Pite, 1986) that in some directions, the support interferes significantly with the rotor response to flow. As the result the rotor sensitivity is azimuthally non-uniform (see Figure 8). Further anisotropy is contributed by the presence of the load-bearing rods of the RCM mounting frame. Since no corrections for these effects were made in processing these data, they contribute an imprecision in speed of about $\pm 7\%$.

In the 'vane follower' configuration uncertainties in direction measurement arise from the following sources: nonlinearity in vane response to current; non-linearity in encoded compass reading to vane position; inaccuracy in carrying the reference direction up the 20 m of hydraulic hose and aluminum pipe from the instrument case to the crossbar at the surface; and inaccuracy in referencing the crossbar orientation to geographic north. The nonlinearity in vane response to current arises from the interaction of the flow with the 3 rods supporting the vane bearing and the 2 thicker rods supporting the current meters (Pite, personal communication). Vane orientations aligned with a downstream support rod are avoided. Since no correction has been made for this effect in processing these data, an imprecision of about $\pm 7^\circ$ in direction is thereby contributed. The non-linearity in compass response to vane position arises from the interference of the geomagnetic field and any

CURRENT METERS — Short Term

| STN. | APRIL | MAY | JUNE |
|------|-------|-------|-------|
| CM57 | _____ | _____ | |
| CM58 | _____ | _____ | |
| CM62 | _____ | _____ | |
| CM63 | _____ | _____ | |
| CM65 | _____ | _____ | |
| CM66 | _____ | _____ | |
| CM71 | _____ | _____ | |
| CM72 | _____ | _____ | |
| CM74 | _____ | _____ | |
| CM79 | _____ | _____ | |
| CM81 | _____ | _____ | _____ |
| CM82 | _____ | _____ | _____ |
| CM83 | _____ | _____ | _____ |
| CM86 | _____ | _____ | _____ |
| CM87 | _____ | _____ | |

CURRENT METERS — Long Term

| STATION | 1983 | | | | | | | | | 1984 | | | | |
|---------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY |
| CM 71 (73 m) | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| CM 71 (123m) | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ | _____ |

TIDE GAUGES

| | APRIL | MAY |
|-----------------|-------|-------|
| CAPE COCKBURN | _____ | _____ |
| BYAM MARTIN CH. | _____ | _____ |

Figure 7. Bar chart of operational periods for recordings instrumentation.

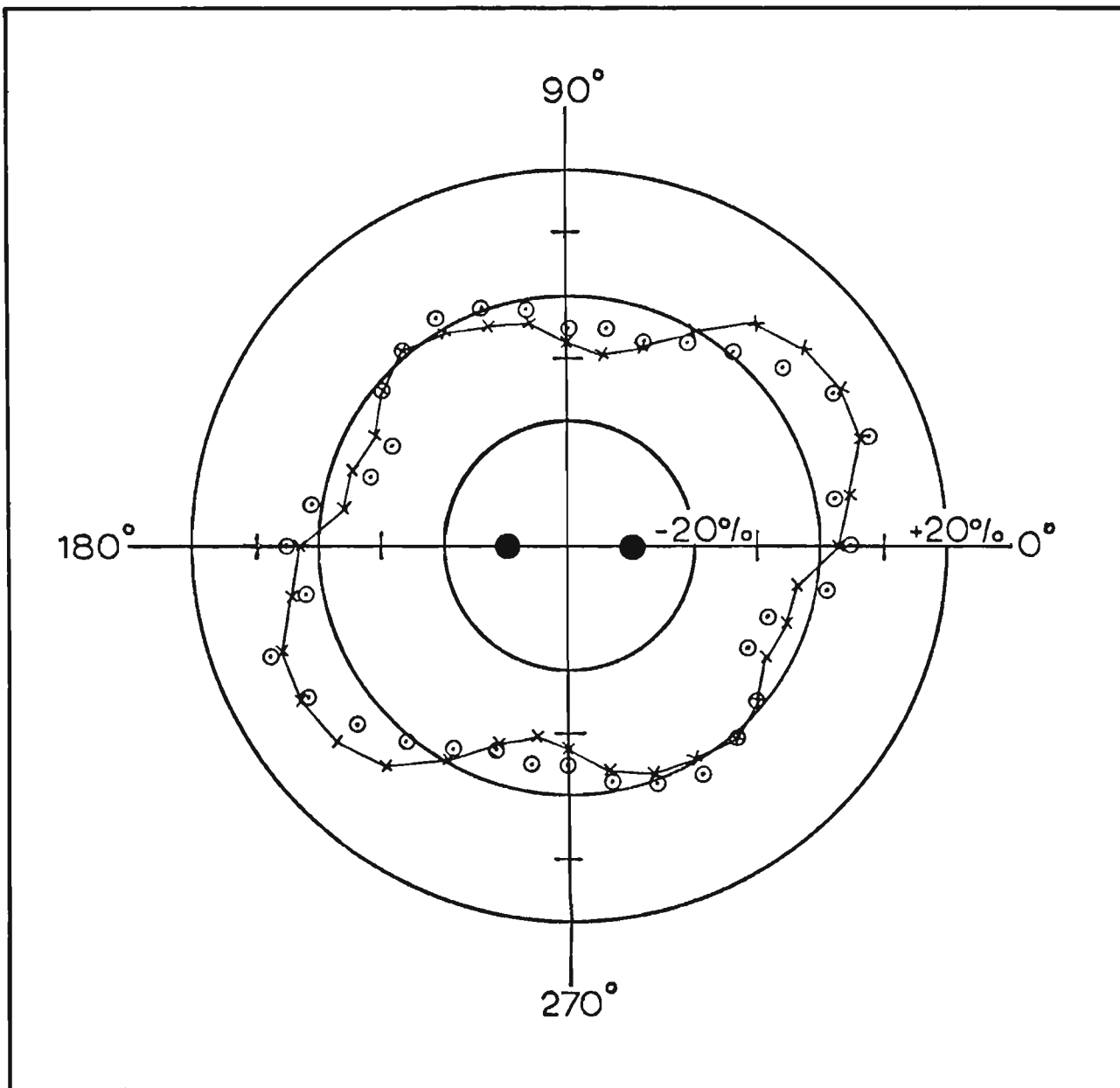


Figure 8. Plot of current meter rotor sensitivity versus azimuth for a two rod support configuration.

remnant magnetism in the instrument case with the magnetic coupling between the vane magnets and the compass, from any departure in concentricity between the vane and the compass pivots and from nonlinearities in the compass potentiometer. The combined effect of these factors was measured near the mooring sites before deployment (at Rae Point) and appropriate corrections (as large as 11.5° peak-to-peak) were made during processing. The uncertainty in these corrections contributes a further imprecision of $\pm 3^\circ$ to direction measurement. Difficulties in carrying the direction reference from the current meter to the crossbar produce an inaccuracy of about $\pm 5^\circ$, while those in referencing the crossbar orientation to geographic north produce a further inaccuracy of about $\pm 3^\circ$. (Crossbar orientation was determined by measuring the angle between the crossbar and the sun with an astrocompass, and by determining the solar azimuth from sun tables knowing the measurement time and position). For the long pipe moorings, accuracy and precision are less good. The mooring in 170 m of water contained about 33 lengths of tubing. It is not unreasonable to assume that the bolt holes at opposite ends of each length of 1-inch tubing were misaligned, with a root-mean-square misalignment of 5° . If these misalignments were random, then the uncertainty over 33 lengths grows to about $\pm 30^\circ$. In addition the mooring may be subject to elastic torsional deformation. An investigation of this possibility over a 30 m length of mooring at mid-latitude, where direction could be measured independently by magnetic compass, gave a root-mean-square discrepancy between the two methods of $\pm 5^\circ$ for currents peaking at 50 cm/s. If this discrepancy scales linearly with the length of the mooring then an imprecision of $\pm 15^\circ$ from this source may be estimated for the pipe mooring in Austin Channel at similar currents.

Temperature sensors on the current meters were calibrated in a large insulated sea water bath whose temperature was controlled to within one or two millidegrees Celsius. Sensor output was determined at 6 or 7 temperatures spanning the range, and a cubic polynomial equation for temperature fitted. Bath checks before and after deployment, and *in situ* comparisons with output from a profiling CTD have verified that accuracy and precision equal the resolution of 0.005°C .

Conductivity sensors on the current meters were calibrated in the same bath at two or three different conductivities and a linear equation for conductivity ratio was fitted. Bath salinity was determined by analysis of samples on a Guildline AutoSal salinometer. Experience has shown that bath calibrations are not reliable predictors of *in situ* performance, for reasons which are not well understood. *In situ* comparisons with output from a profiling CTD at the moorings in Prince of Wales Strait in 1982 showed RCM salinity offsets ranging as far as $+0.13$ from laboratory calibrations, with an average departure of $+0.06$. *In situ* comparisons at the other moorings in 1982 were not as well controlled, but yielded similar values. Calibration equations for measurements in 1983 were not, however, adjusted in accordance with the *in situ* calibrations. Accuracy and precision in salinity measurement are thus estimated to be ± 0.1 and ± 0.03 , respectively.

Digiquartz pressure gauges were calibrated by Aanderaa Instruments Ltd., at a single fixed temperature (generally 0°C) by applying known pressures with dead-weight tester (Ruska Model 2465-751-00). Output values at 10-20 different pressures were fitted to a polynomial equation with a precision of approximately 0.01% fs. Reproducibility of deadweight pressures was about 0.05 dbar. Their absolute accuracy depends on the care used in operation and on the attention paid to such factors as hydraulic heads and air bubbles in connecting tubing. A realistic estimate is 0.03 db.

The estimated accuracy and precision of the current meter and tide-gauge sensors are tabulated in Table 2.

Table 3
Estimated Accuracy and Precision of Measurement

| <u>Instrument</u> | <u>Parameter</u> | <u>Accuracy</u> | <u>Precision</u> | <u>Resolution</u> |
|-------------------|--------------------|-----------------|------------------|-------------------|
| RCM4 | Speed (cm/s) | ±2% | ±7% | .05 cm/s |
| RCM4 (hose) | Direction (°T) | ±3° | ±7° | 0.4° |
| RCM4 (pipe) | Direction (°T) | ±30° | ±16° | 0.4° |
| RCM4 | Temperature (°C) | ±.005 | ±.005 | 0.005 |
| RCM4 | Conductivity Ratio | ±.0025 | ±.0008 | 0.00016 |
| TG4/WLR5A | Pressure (db) | ±0.03db | ±.005db | 0.001%fs |

4. DATA PROCESSING

The first stage in processing the current meter data was the translation of the information from the original one-quarter inch magnetic tape onto a computer-compatible nine-track magnetic tape. This process was done at the Institute of Ocean Sciences using an HP2100 computer. The data were then read into the Institute's Univac 1100/60 computer for editing. The editing procedure involved timing checks, the truncation of irrelevant pre- and post-deployment data, and the replacement of occasional spurious measurements, or "spikes". Calibration formulae were then applied to the "N" numbers to produce values of the designated parameters, usually speed (cm/sec), direction (degrees True), conductivity ratio, temperature, and sometimes pressure. Salinity and density were then calculated. Salinity was calculated using the Practical Salinity Scale 1978 (Lewis, 1981). Density was presented as sigma-t (σ_t), from the relationship,

$$\sigma_t = (\text{density (gm/cm}^3\text{)} - 1) \times 10^3.$$

After the data had been converted to real values, they were stored on magnetic tape. Each file on a tape contains information from one instrument. The files begin with a header which indicates such things as instrument number, station location, and station designation. These are followed by eleven channels of calibrated data as follows:

- channel 1 - time
- 2 - speed
- 3 - direction
- 4 - high resolution temperature
- 5 - salinity
- 6 - pressure
- 7 - conductivity ratio
- 8 - sigma-t
- 9 - low resolution temperature
- 10 - time code generator
- 11 - voltage reference

All channels were not always used in each instance.

Similar procedures were used to process the tide gauge data.

5. DATA PRESENTATION

The calibrated and corrected current meter data are presented in the Appendix as time series plots of current speed, direction, temperature, and salinity. Superimposed on the speed and direction traces with a heavier pen are low-pass filtered values of the same (tidal signal removed). One month of data is displayed per page.

For the tide-gauge measurements, only one month of representative data is shown.

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APPENDIX

Recording instrument data index and time-series plots.

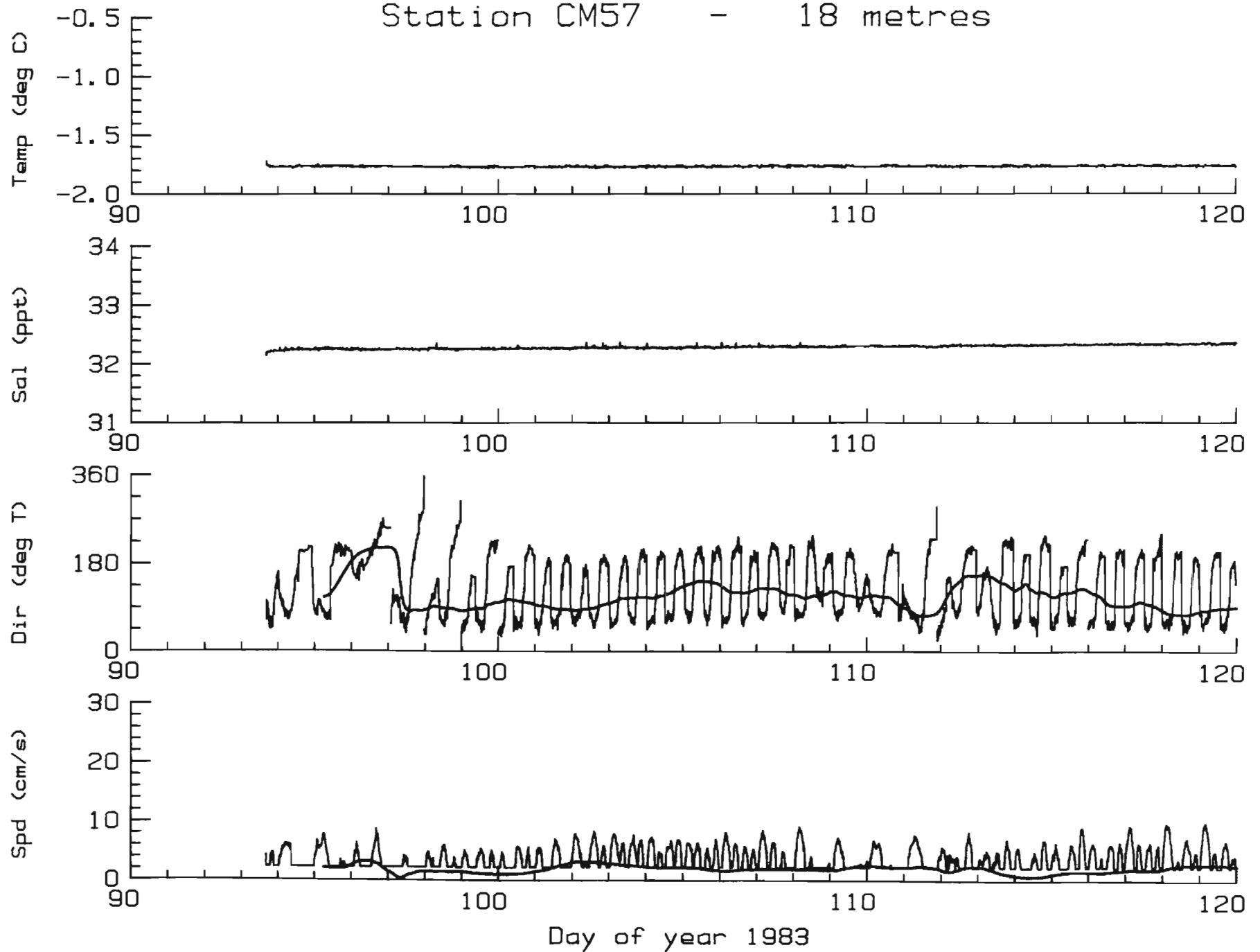
RECORDING INSTRUMENT DATA INDEXCURRENT METERS

| <u>STATION</u> | <u>PAGE</u> | <u>STATION</u> | <u>PAGE</u> | <u>STATION</u> | <u>PAGE</u> |
|----------------|-------------|----------------|-------------|----------------|-------------|
| CM57 | 23 | CM71- 18m | 34 | CM81 | 70 |
| CM58 | 25 | CM71- 73m | 36 | CM82 | 73 |
| CM62 | 27 | CM71- 123m | 50 | CM83 | 76 |
| CM63 | 29 | CM72 | 64 | CM86 | 79 |
| CM65 | 31 | CM74 | 66 | CM87 | 82 |
| CM66 | 32 | CM79 | 68 | | |

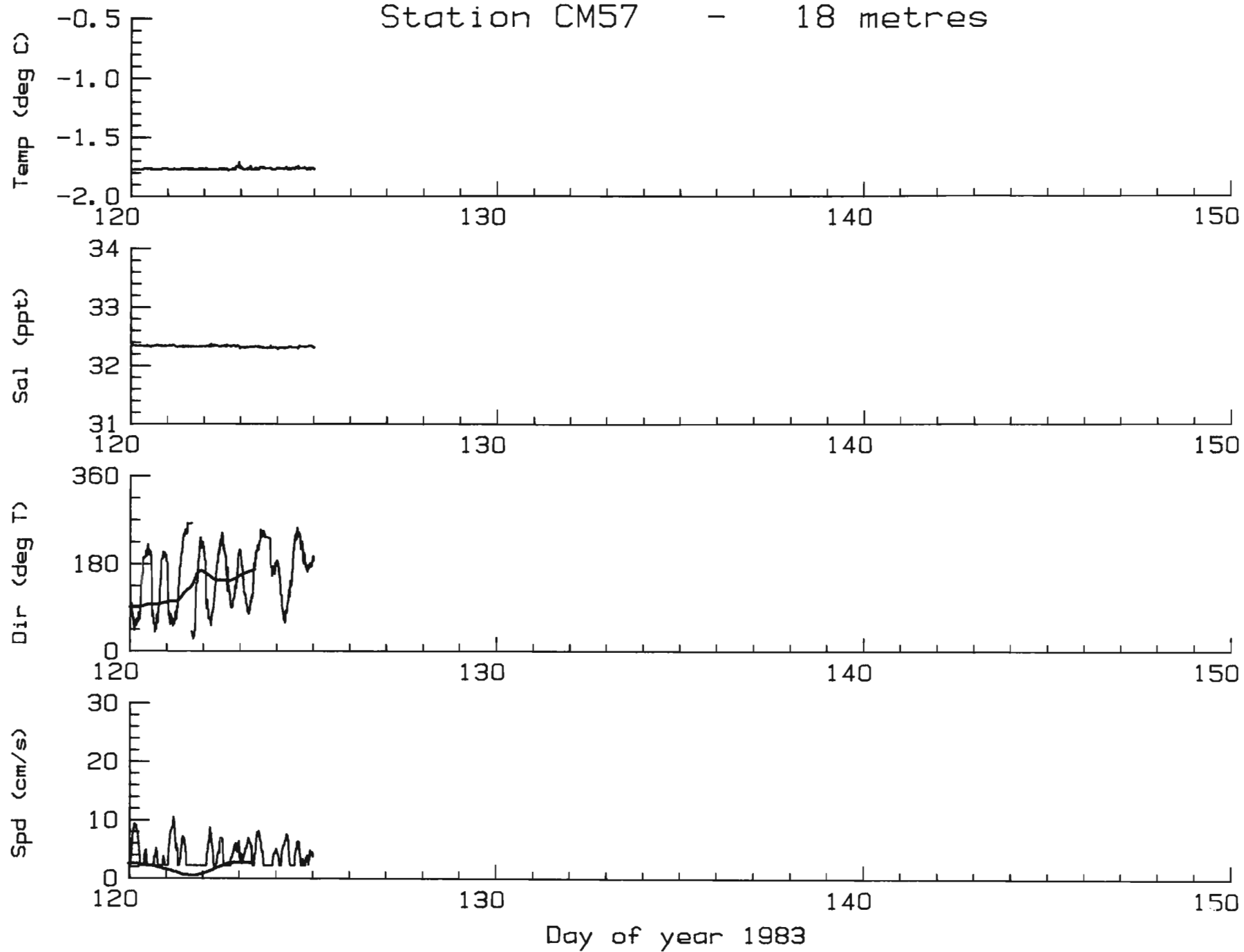
TIDE GAUGES

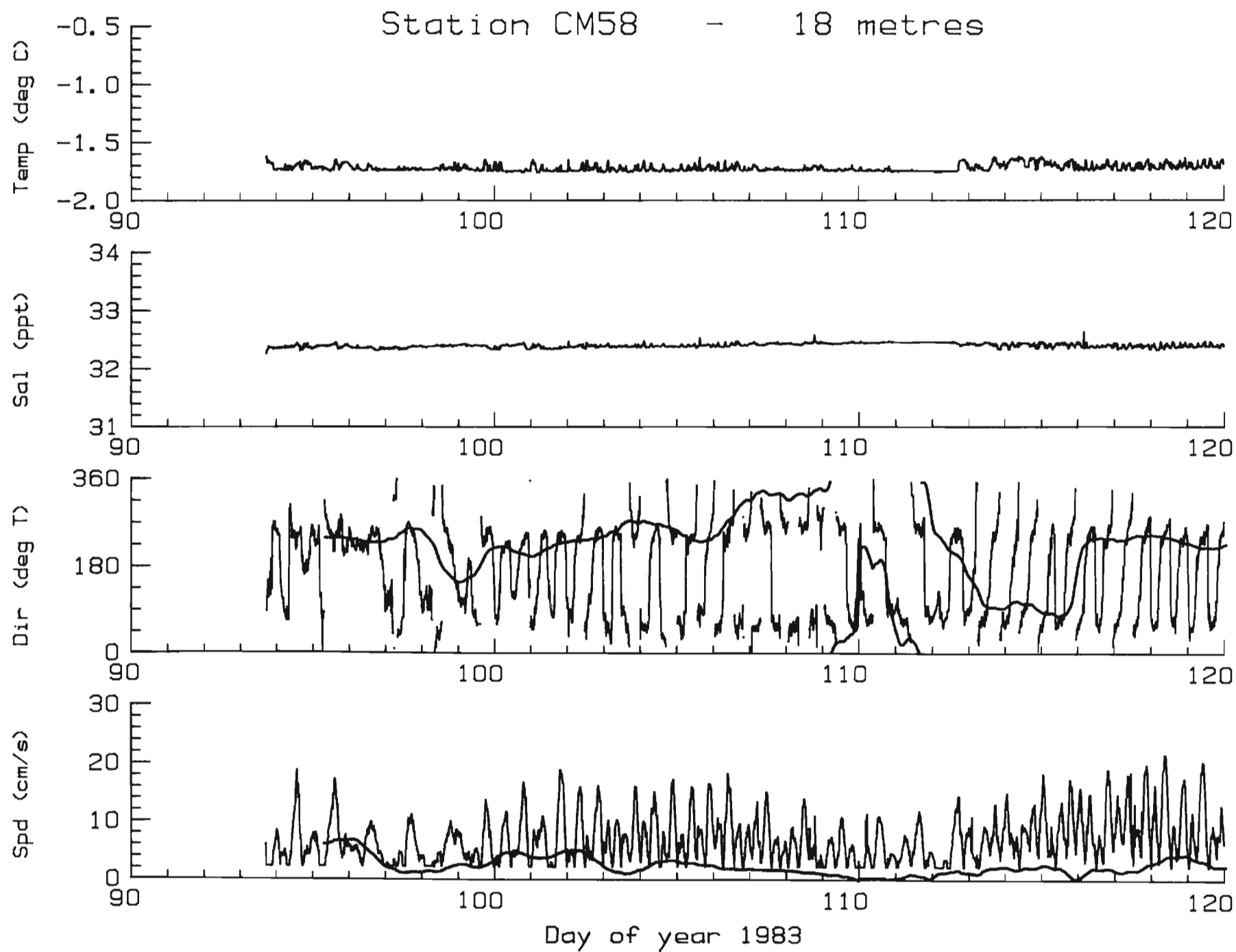
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|---------------------|-------------|
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| Byam Martin Channel | 84 |

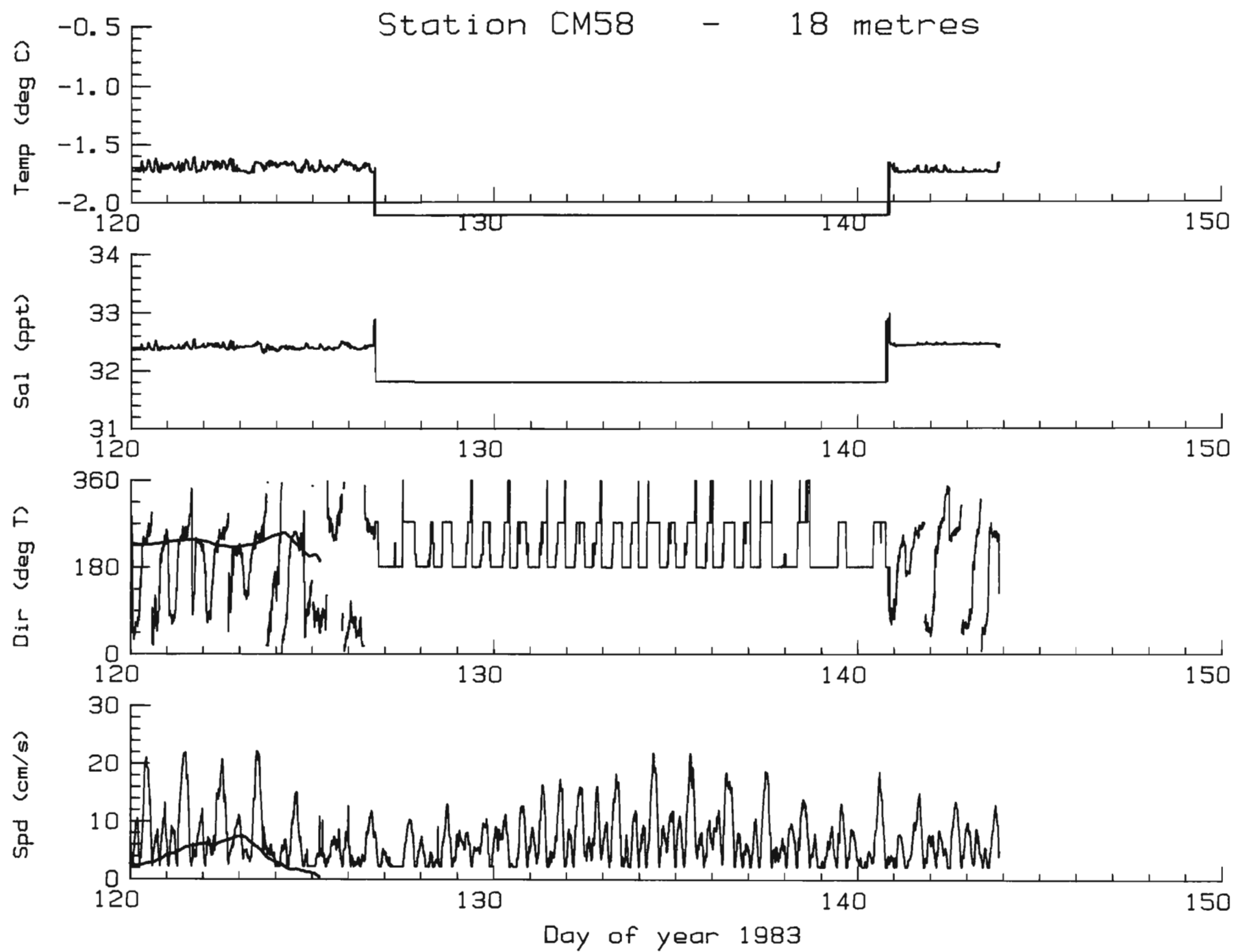
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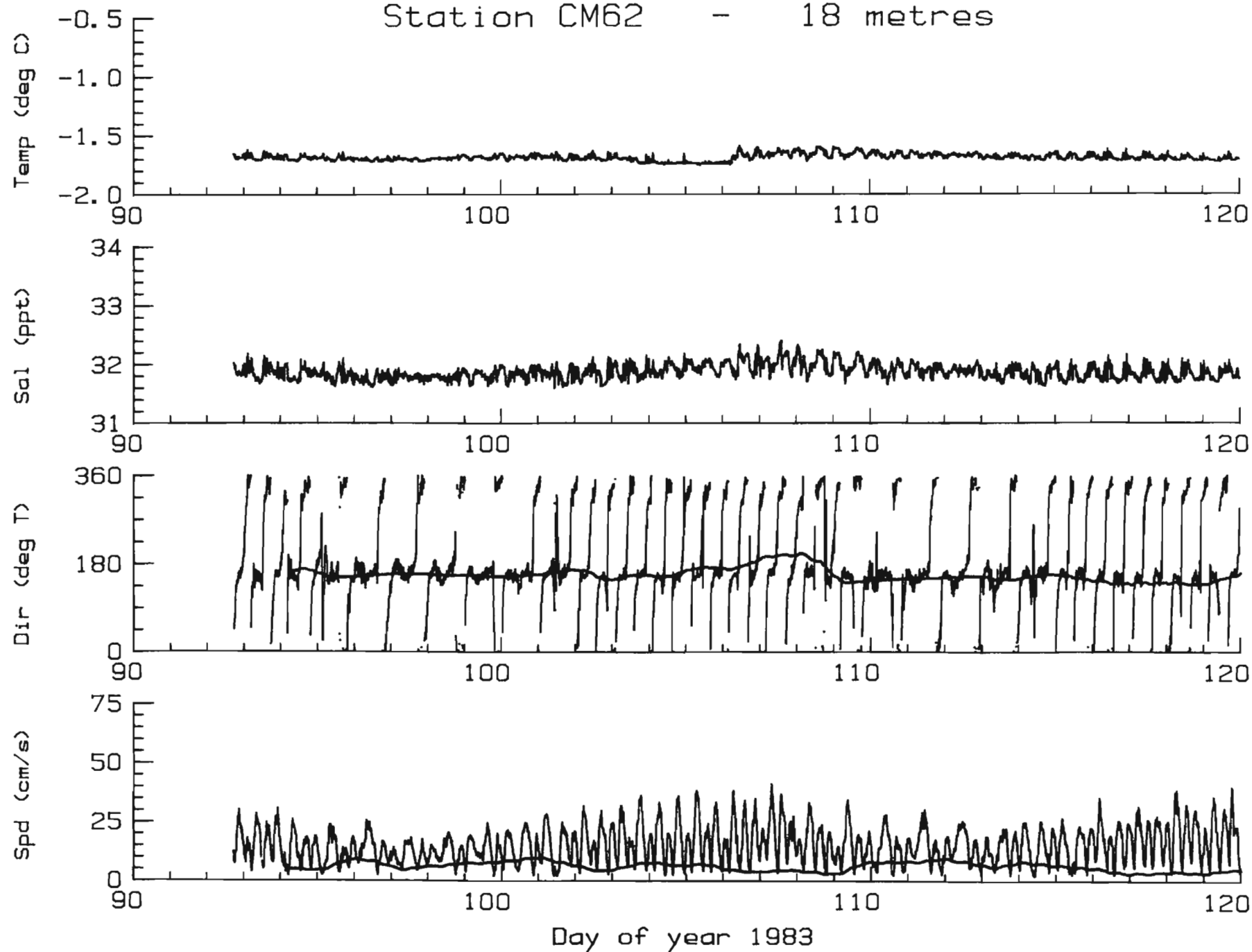
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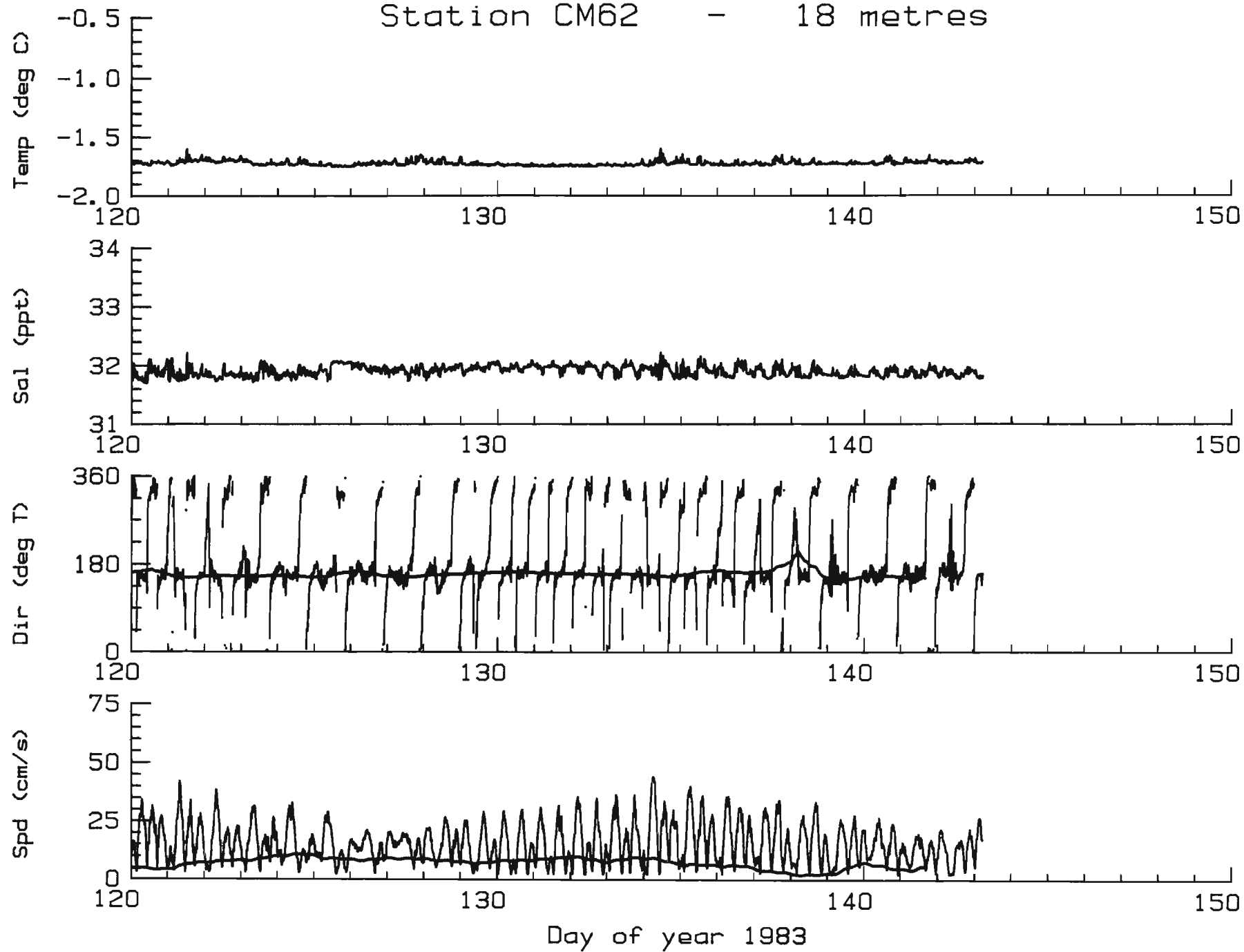




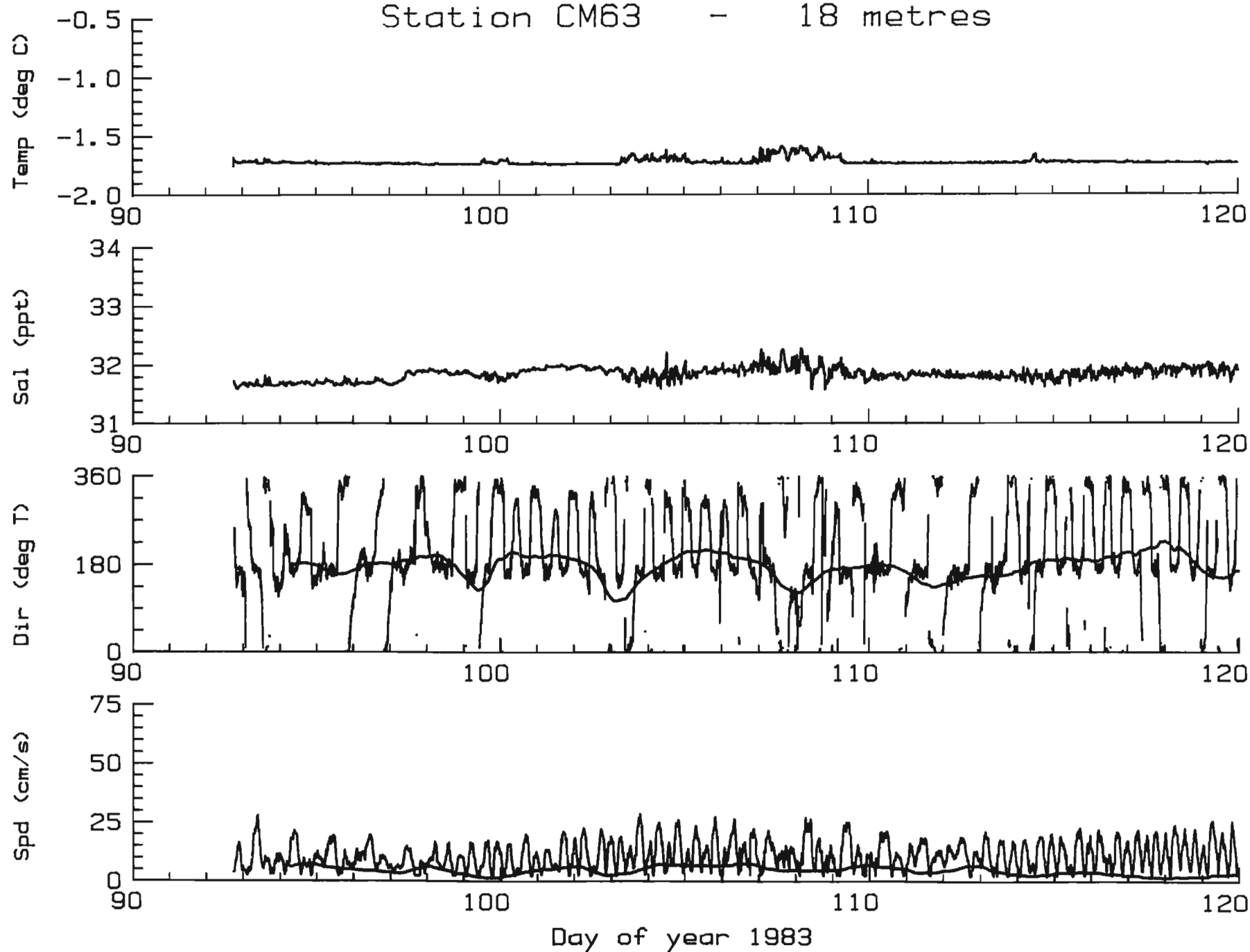
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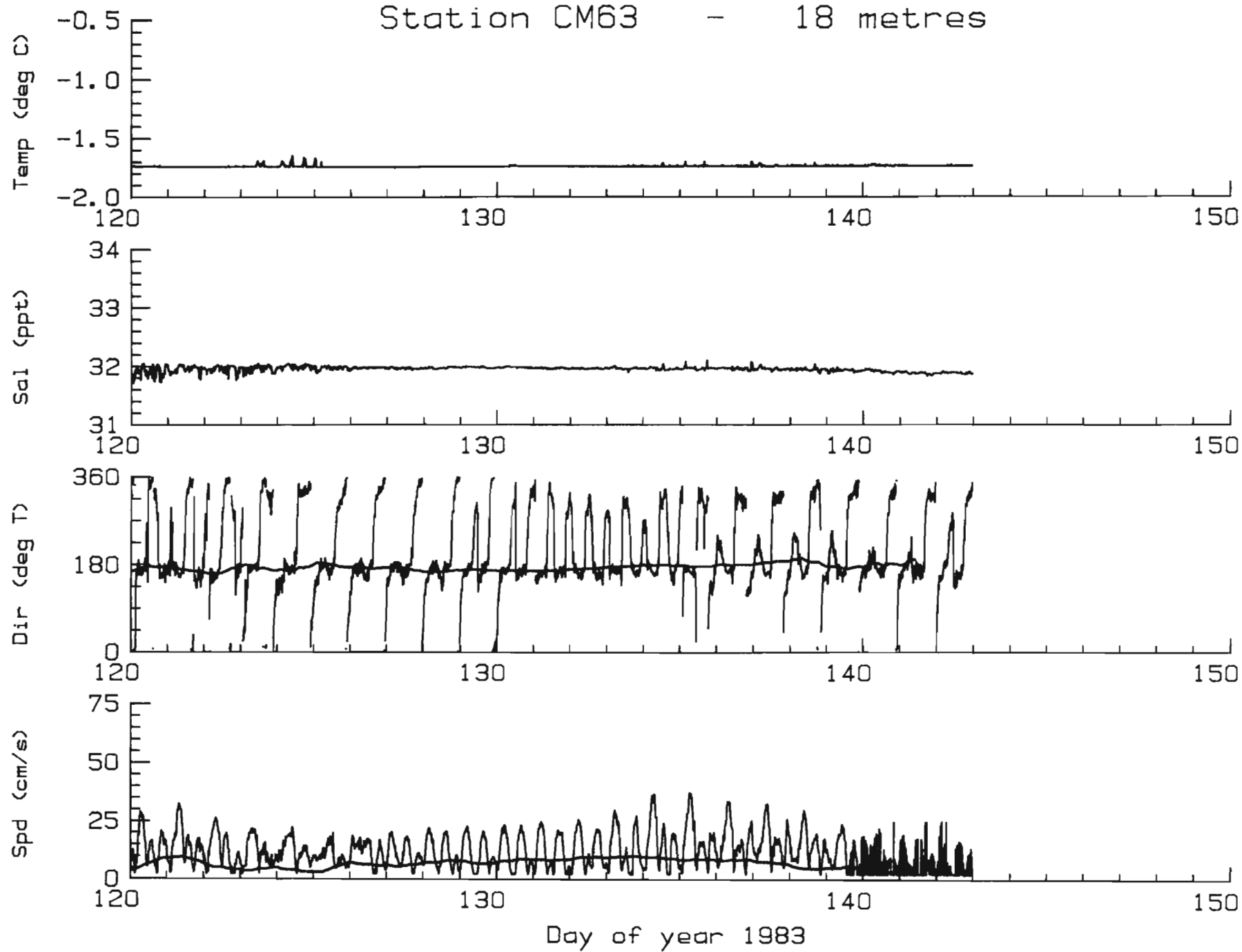
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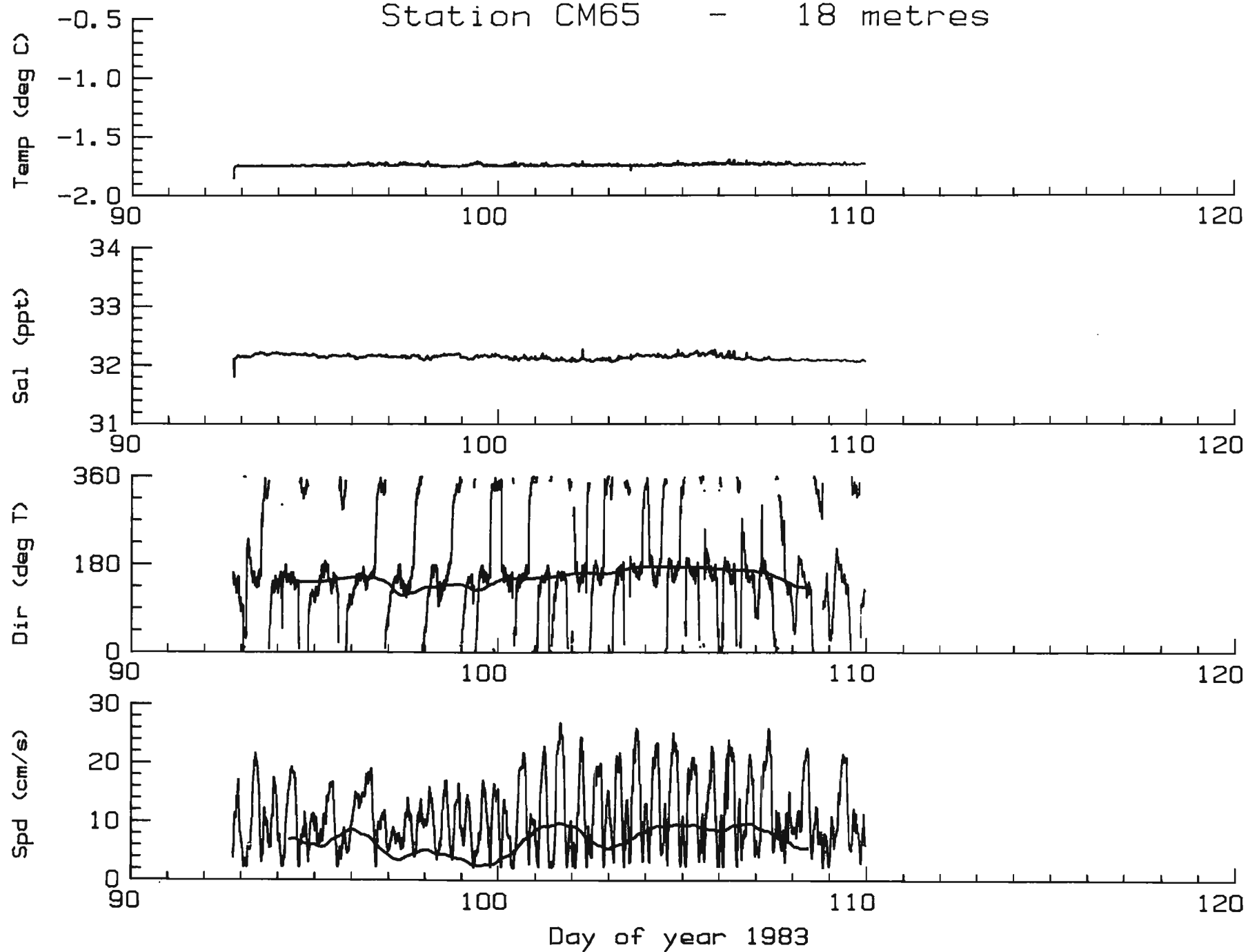
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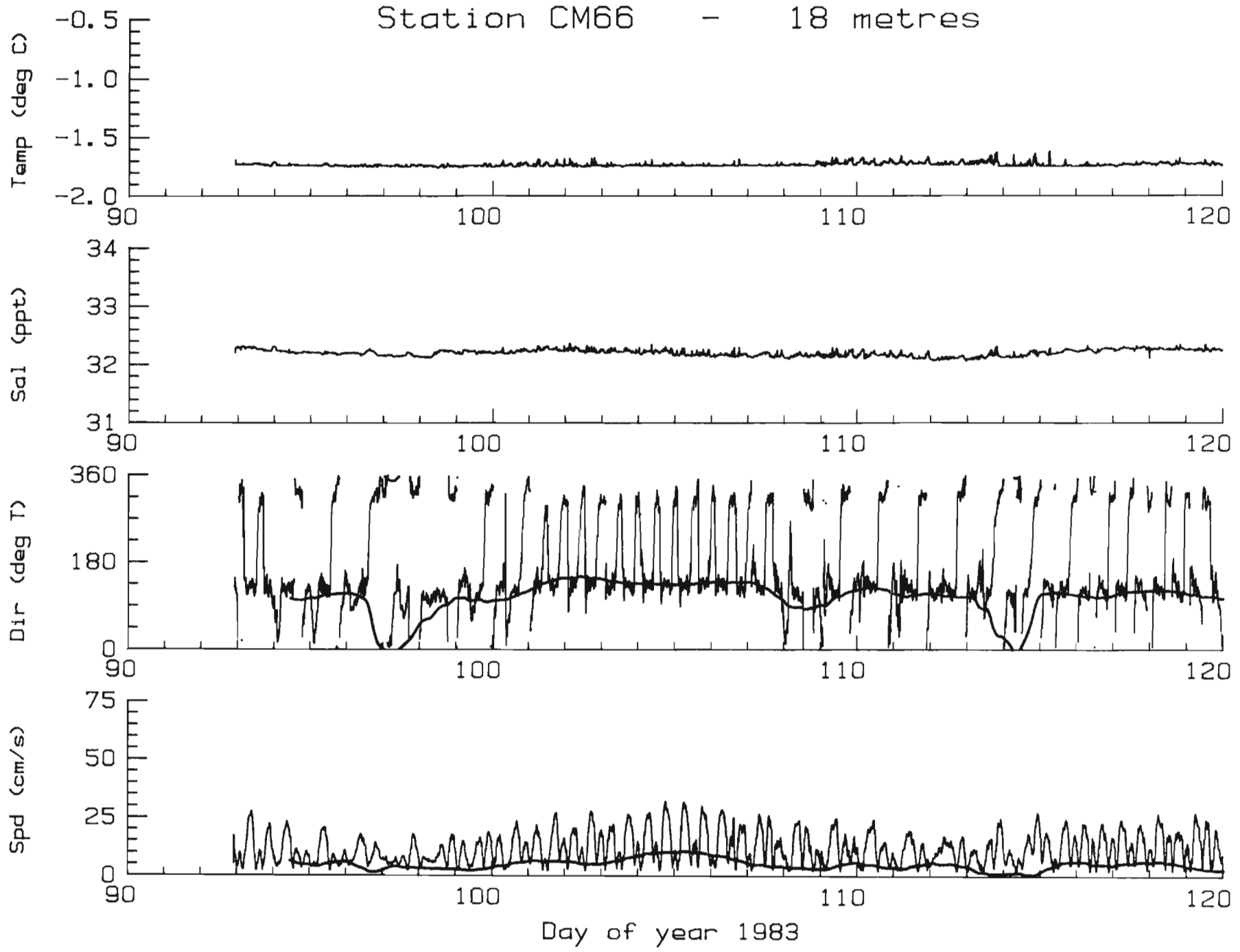
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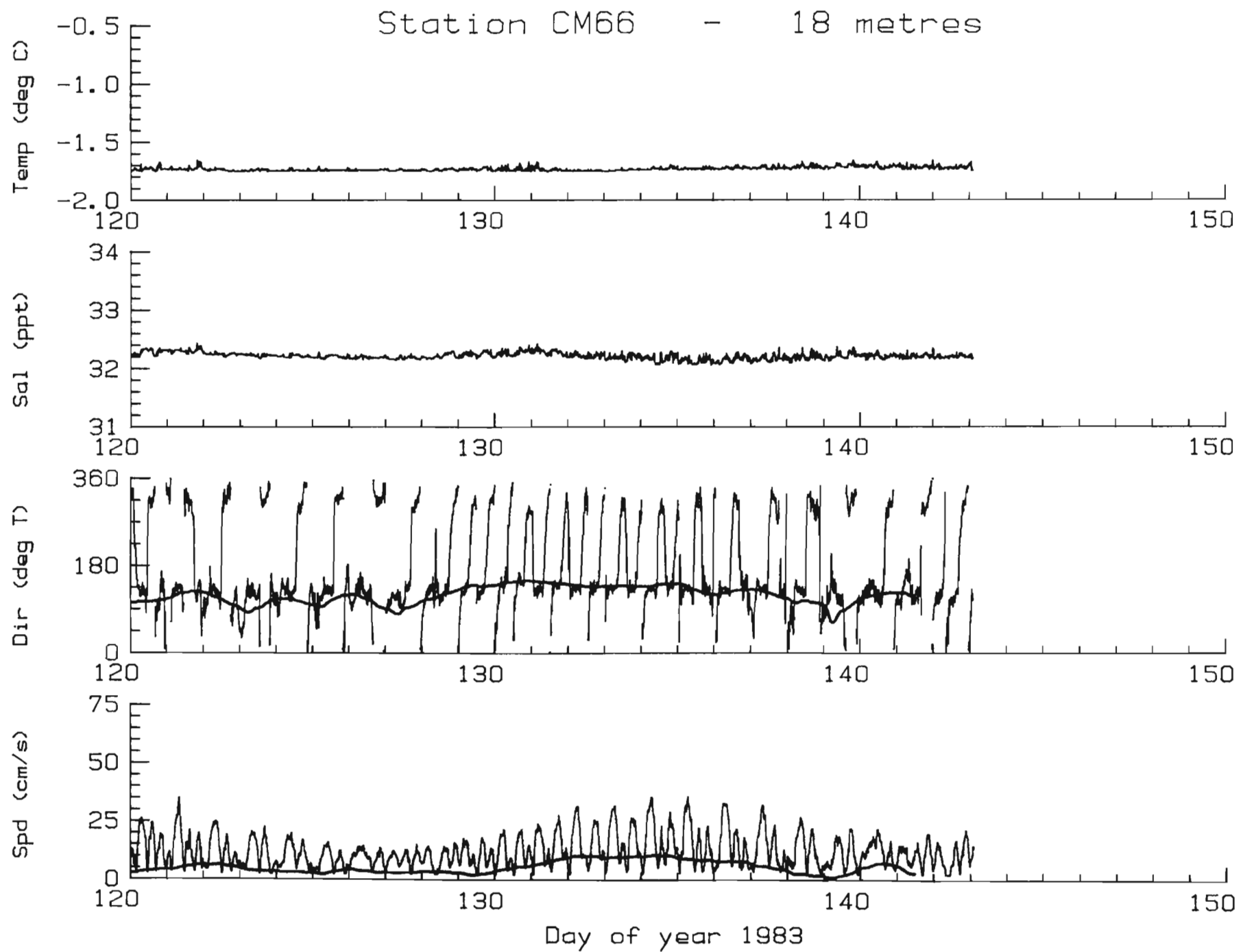


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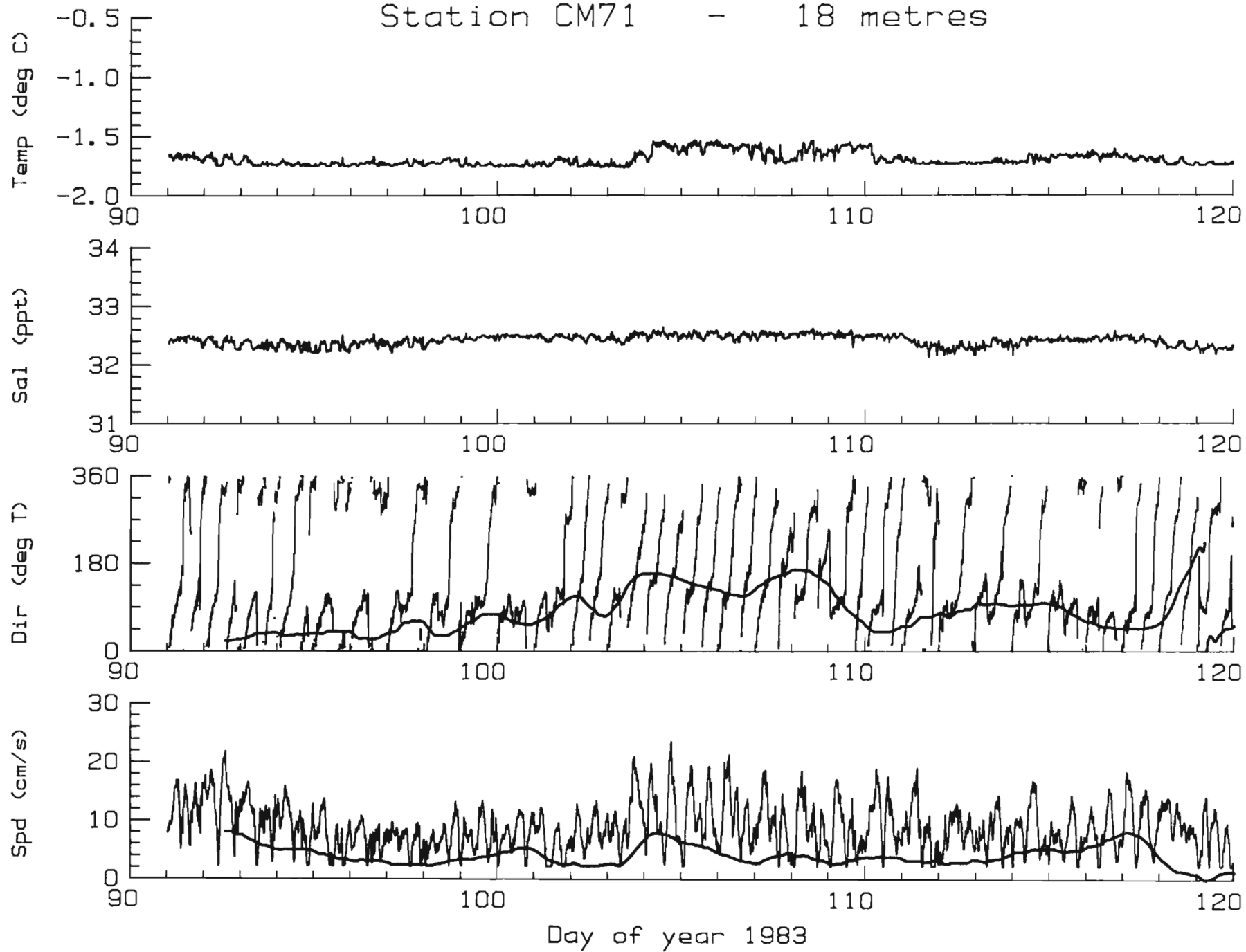


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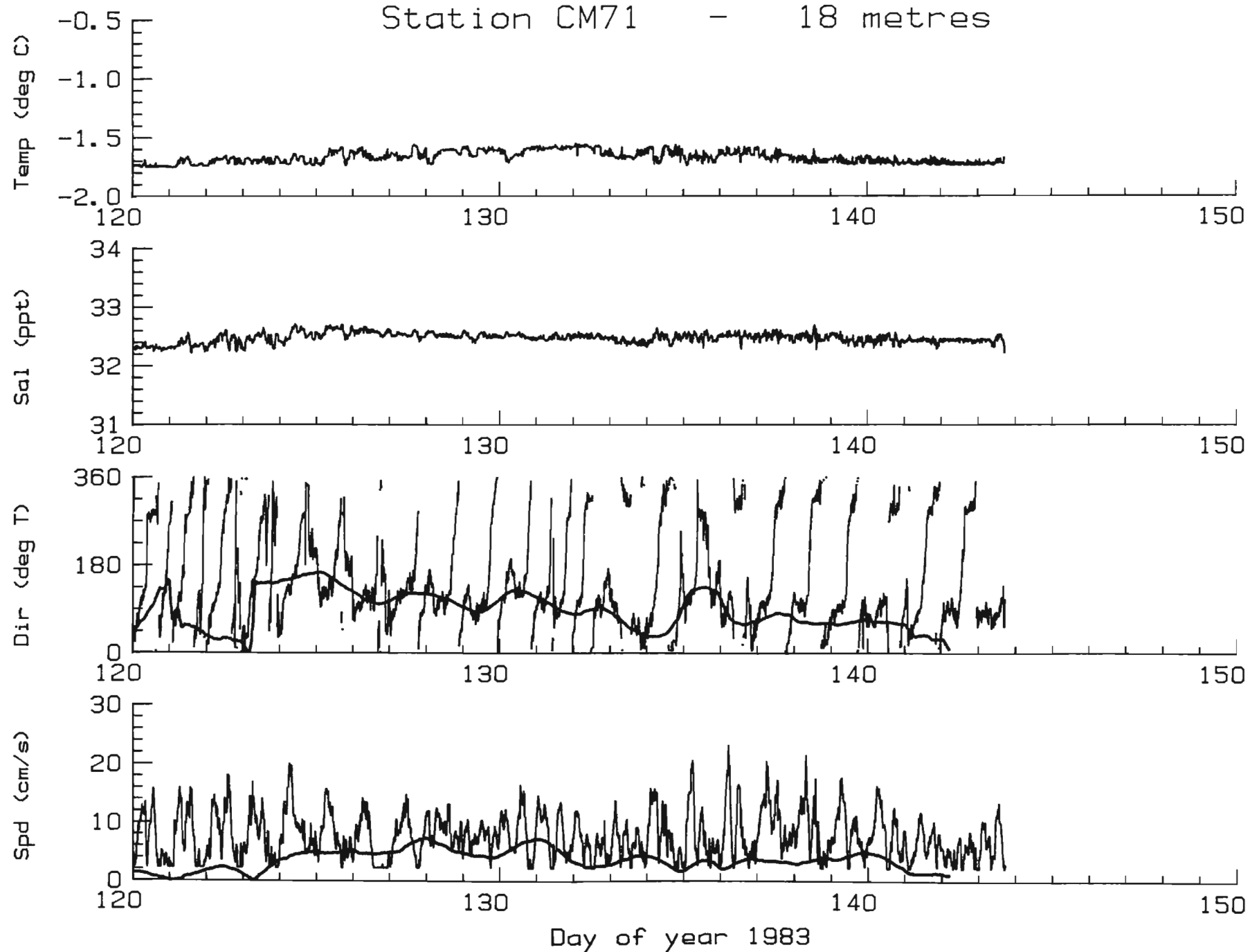


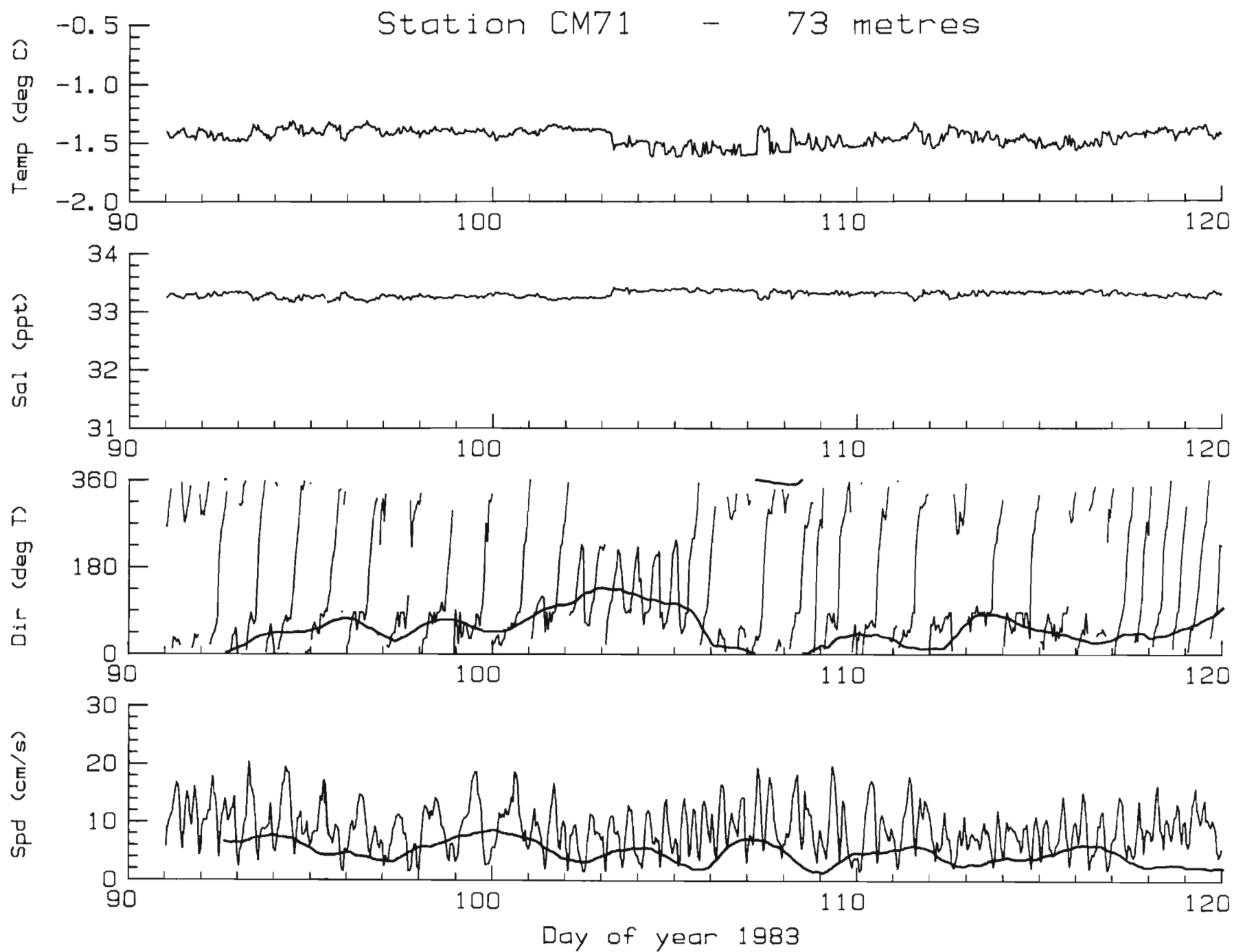


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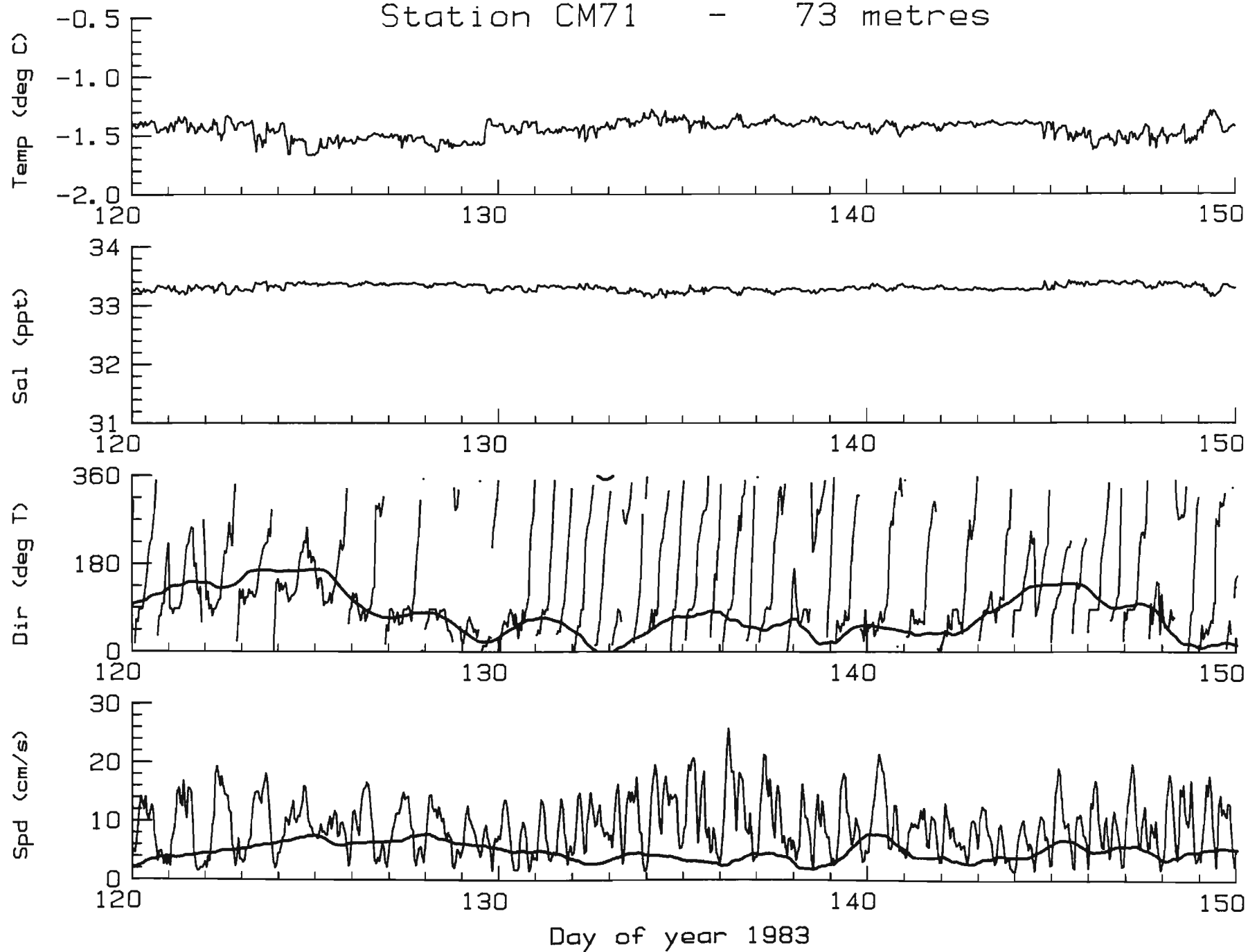


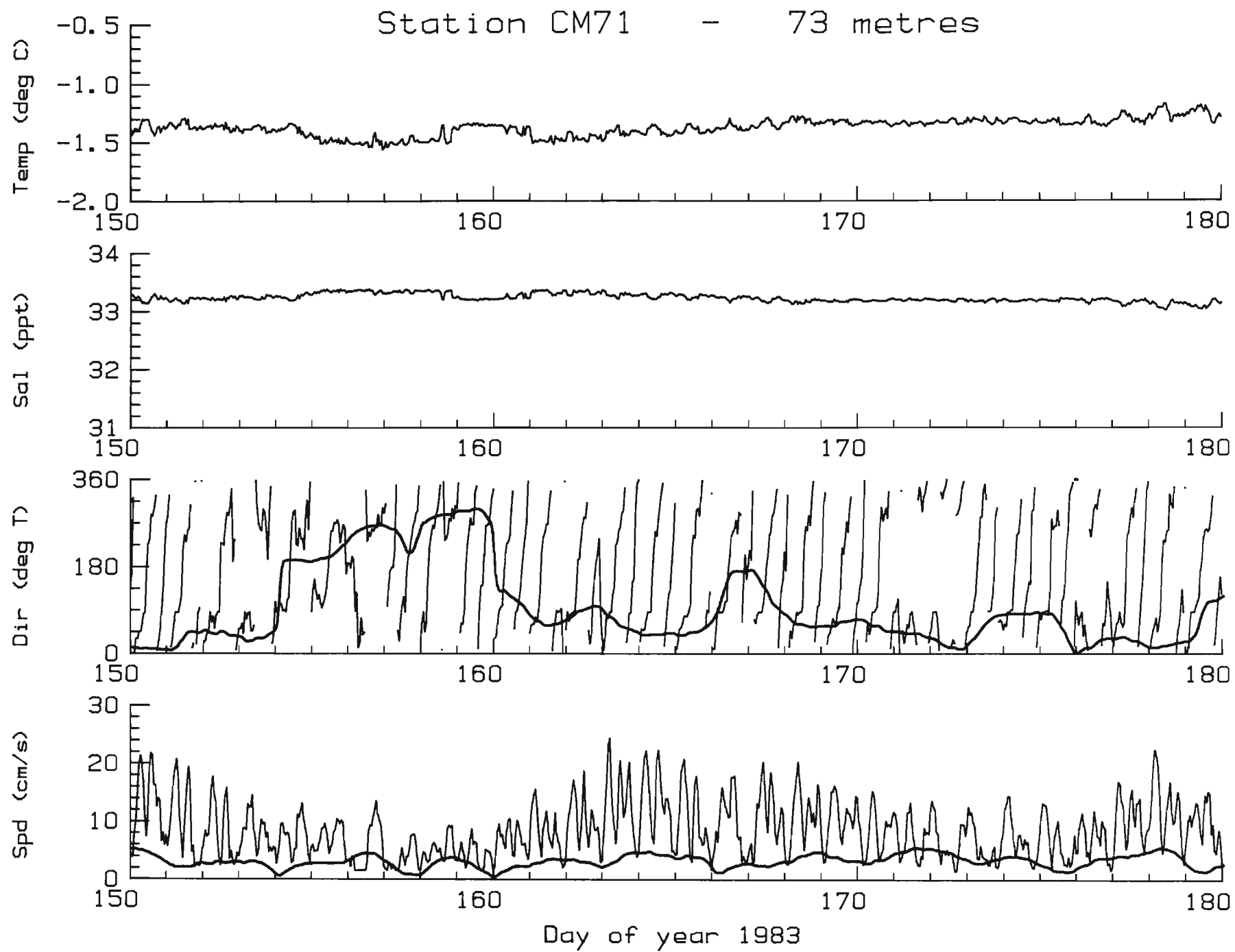
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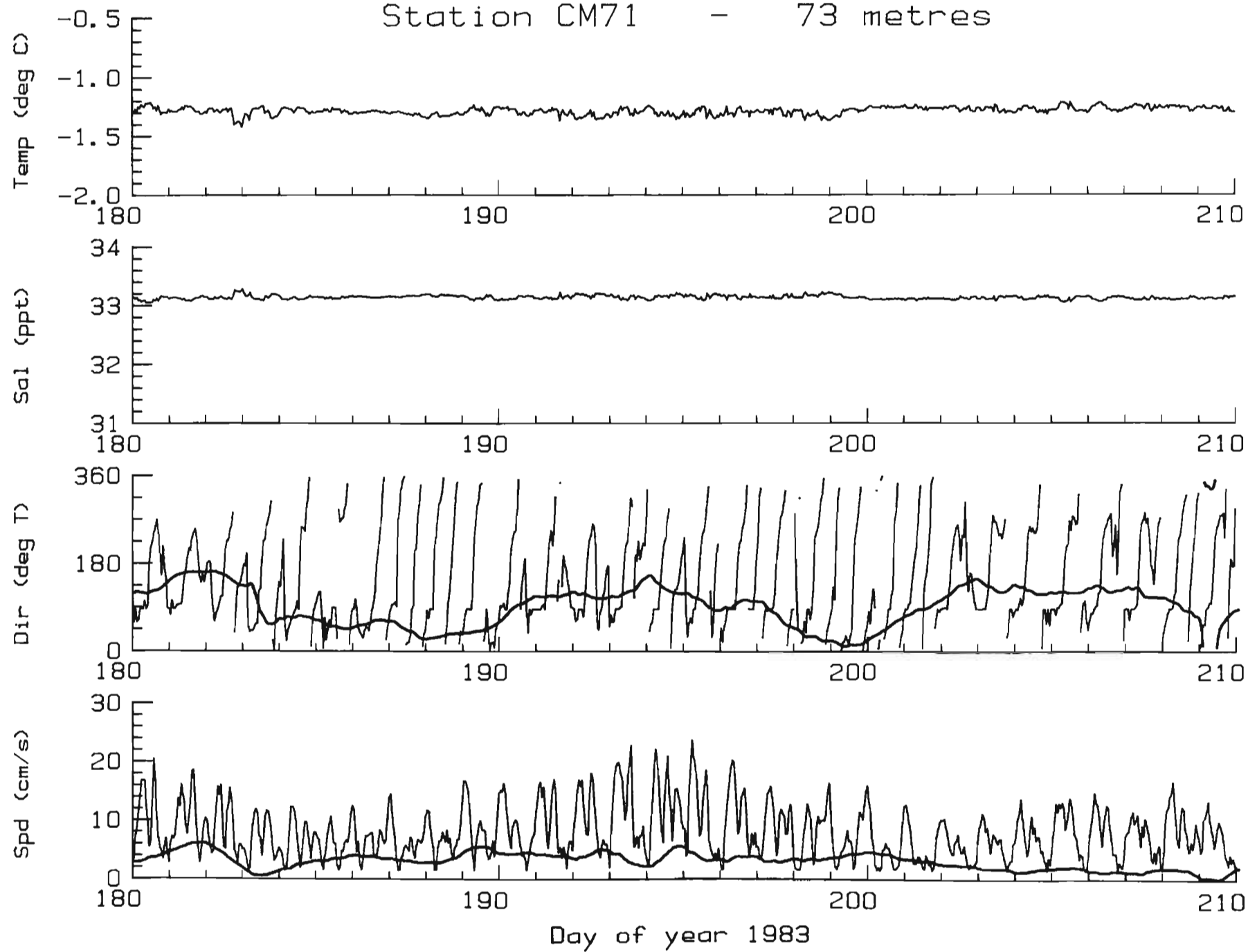


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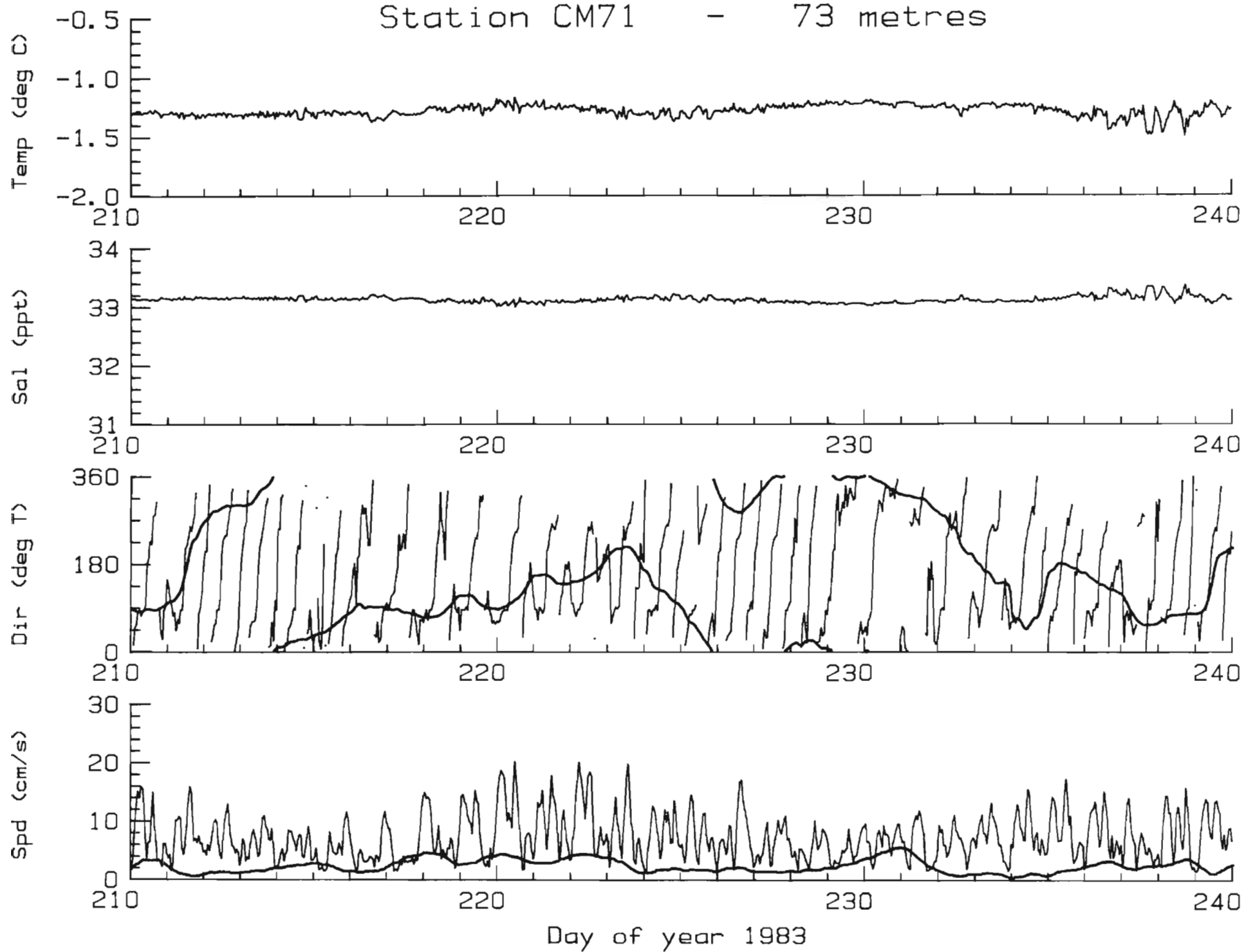


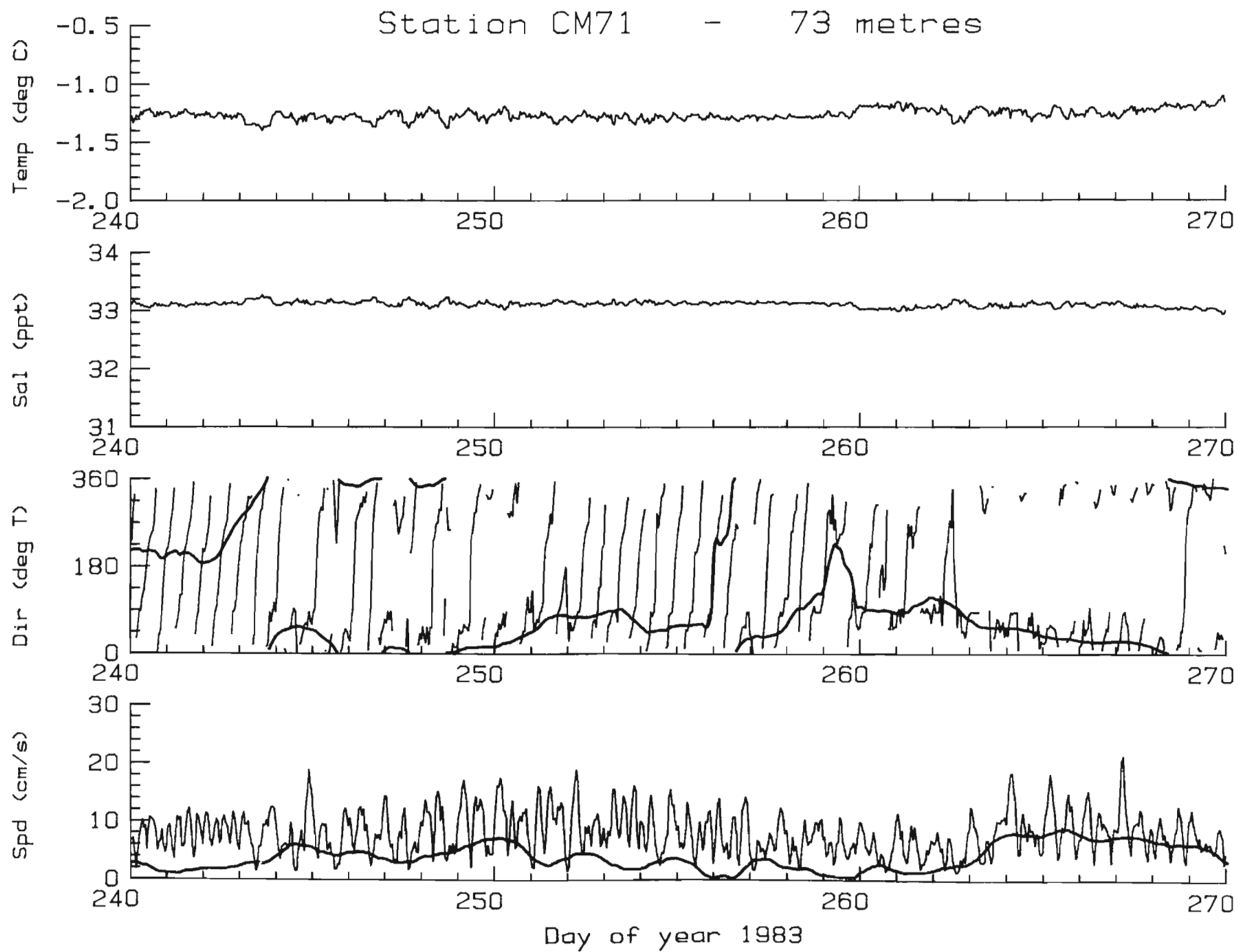


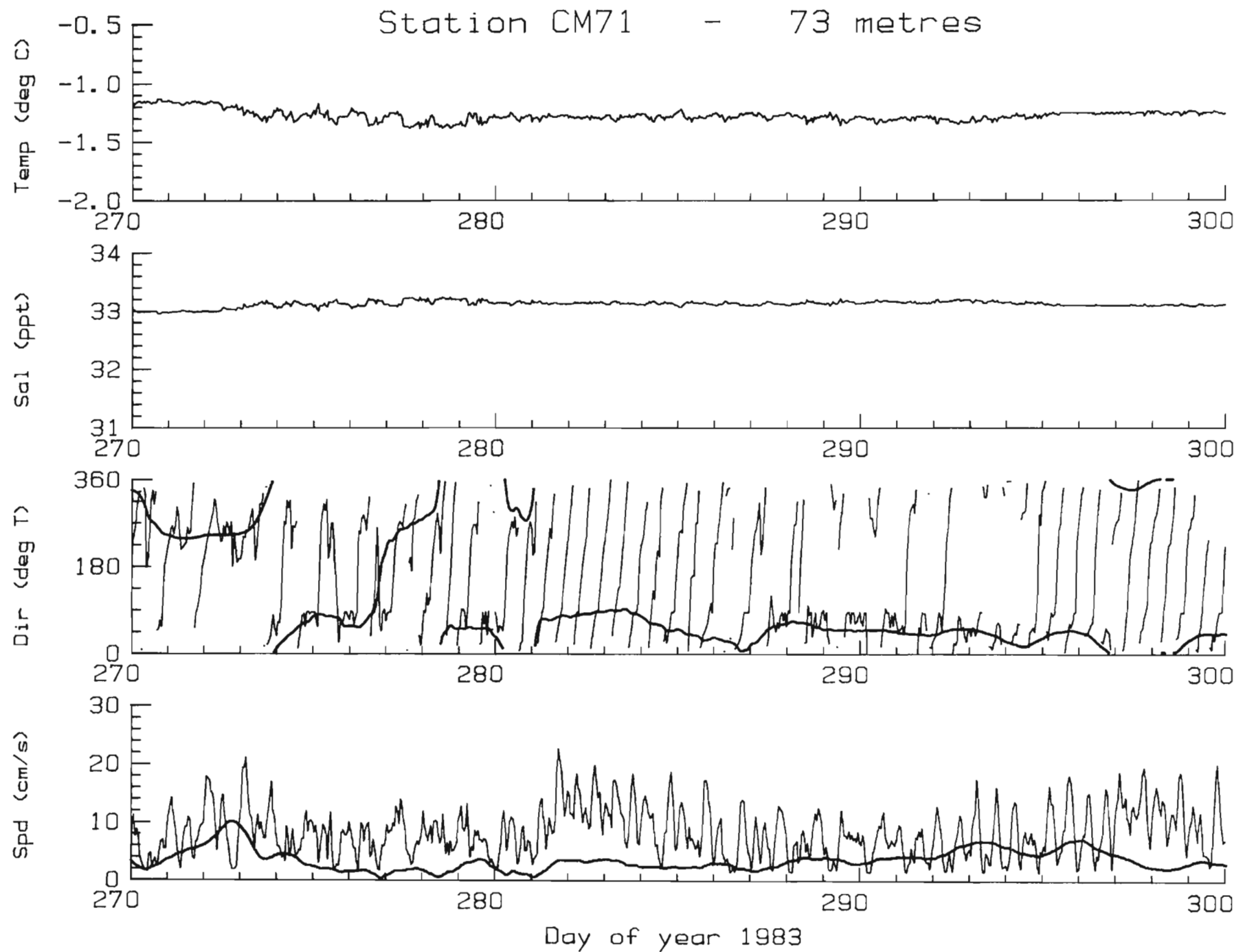
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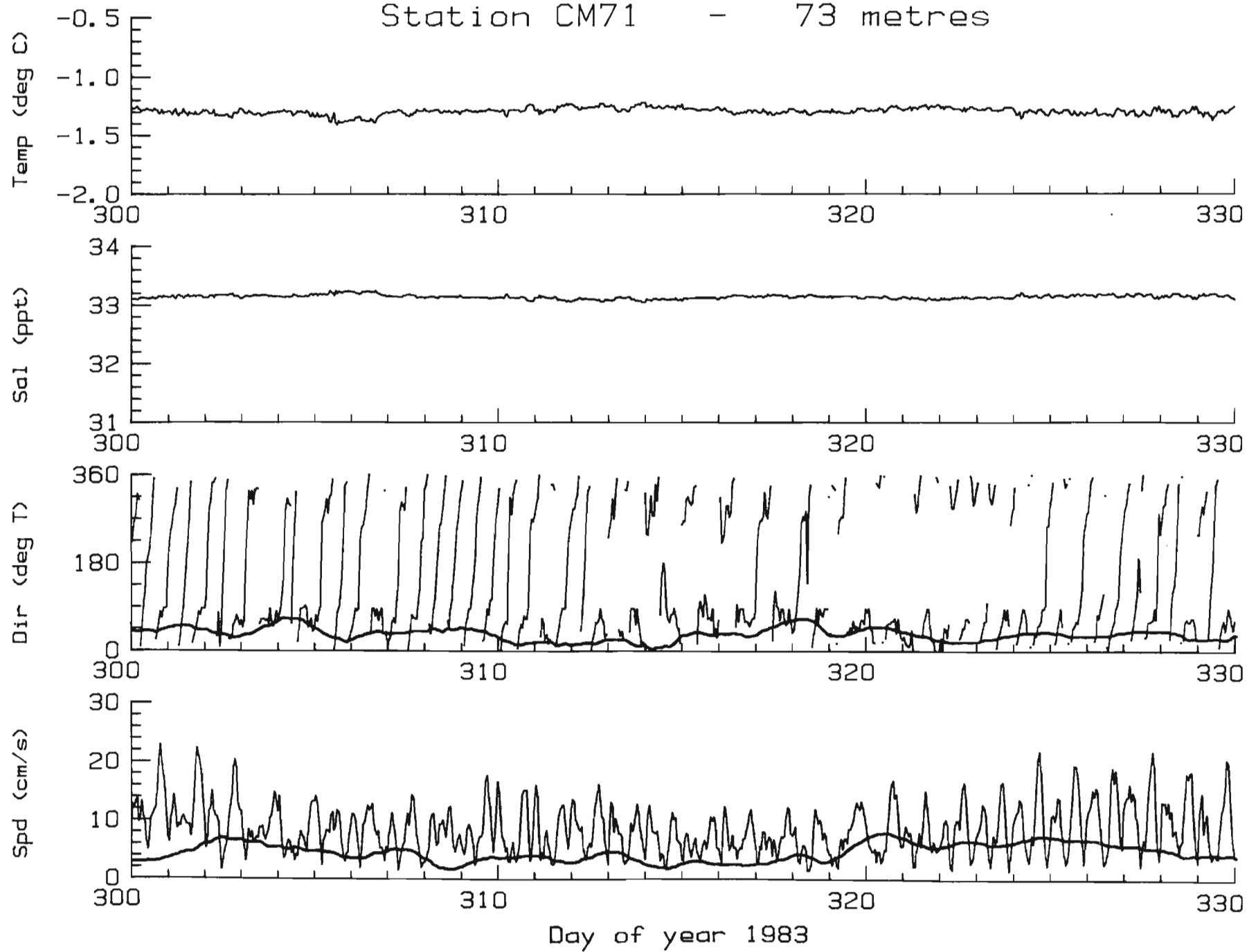
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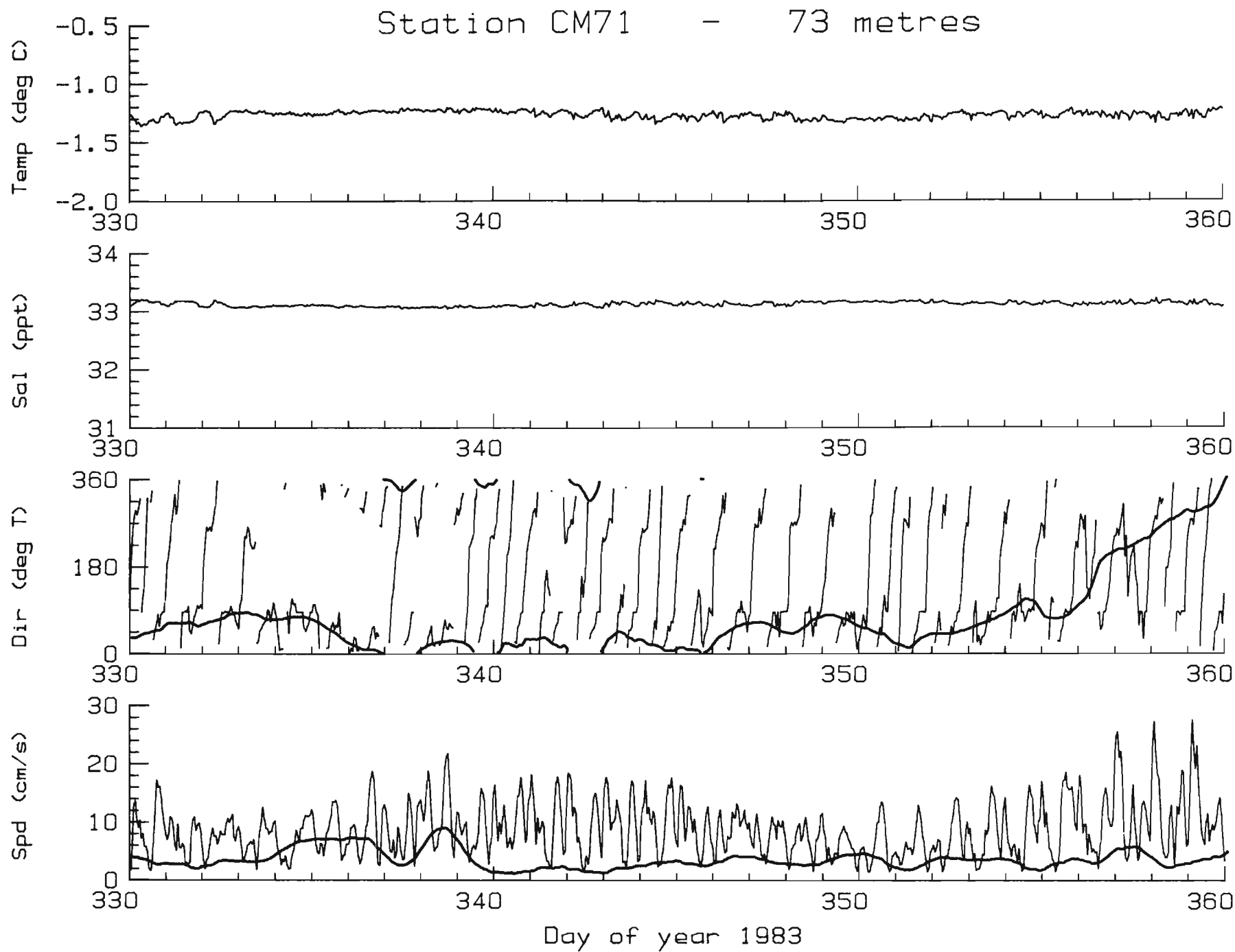




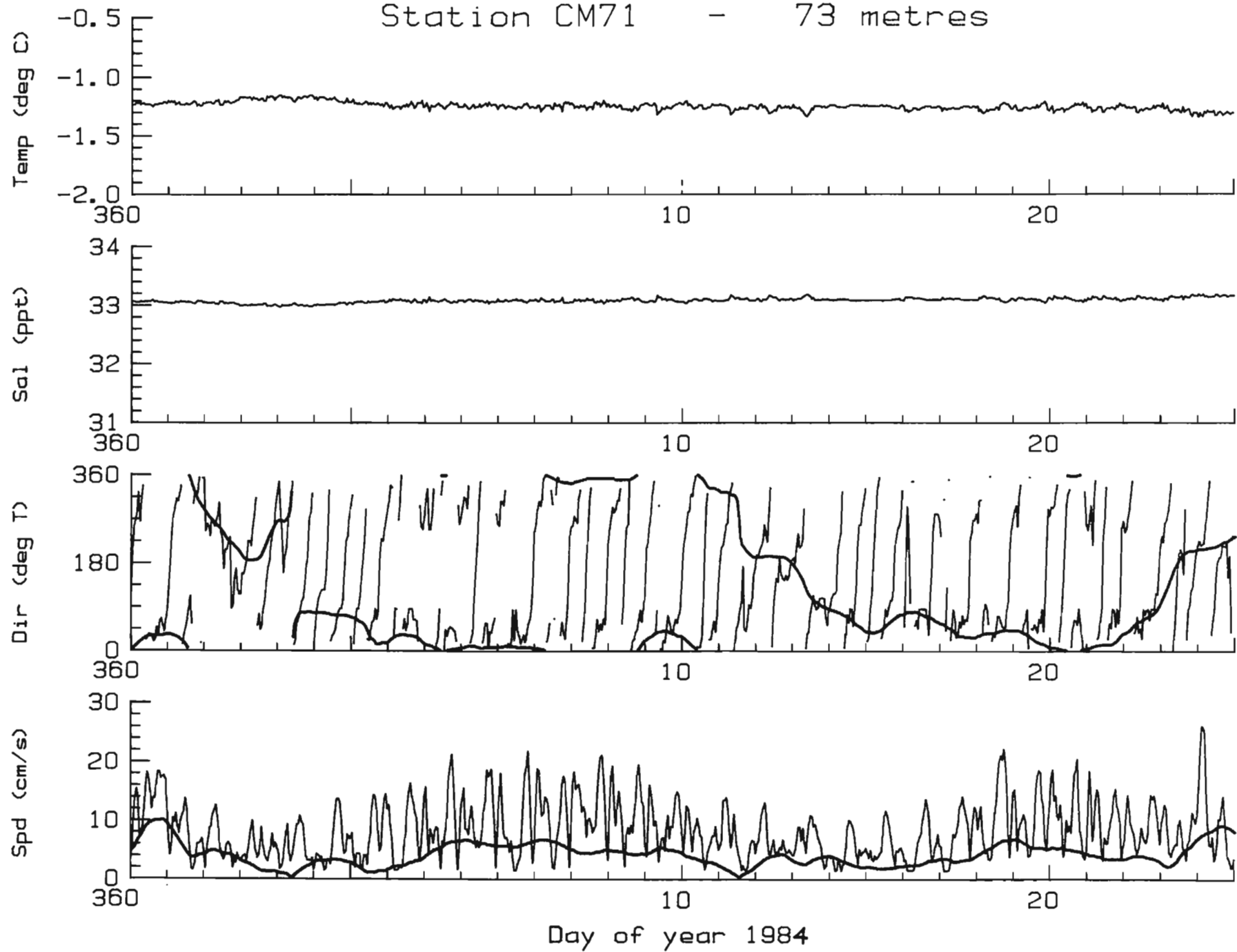


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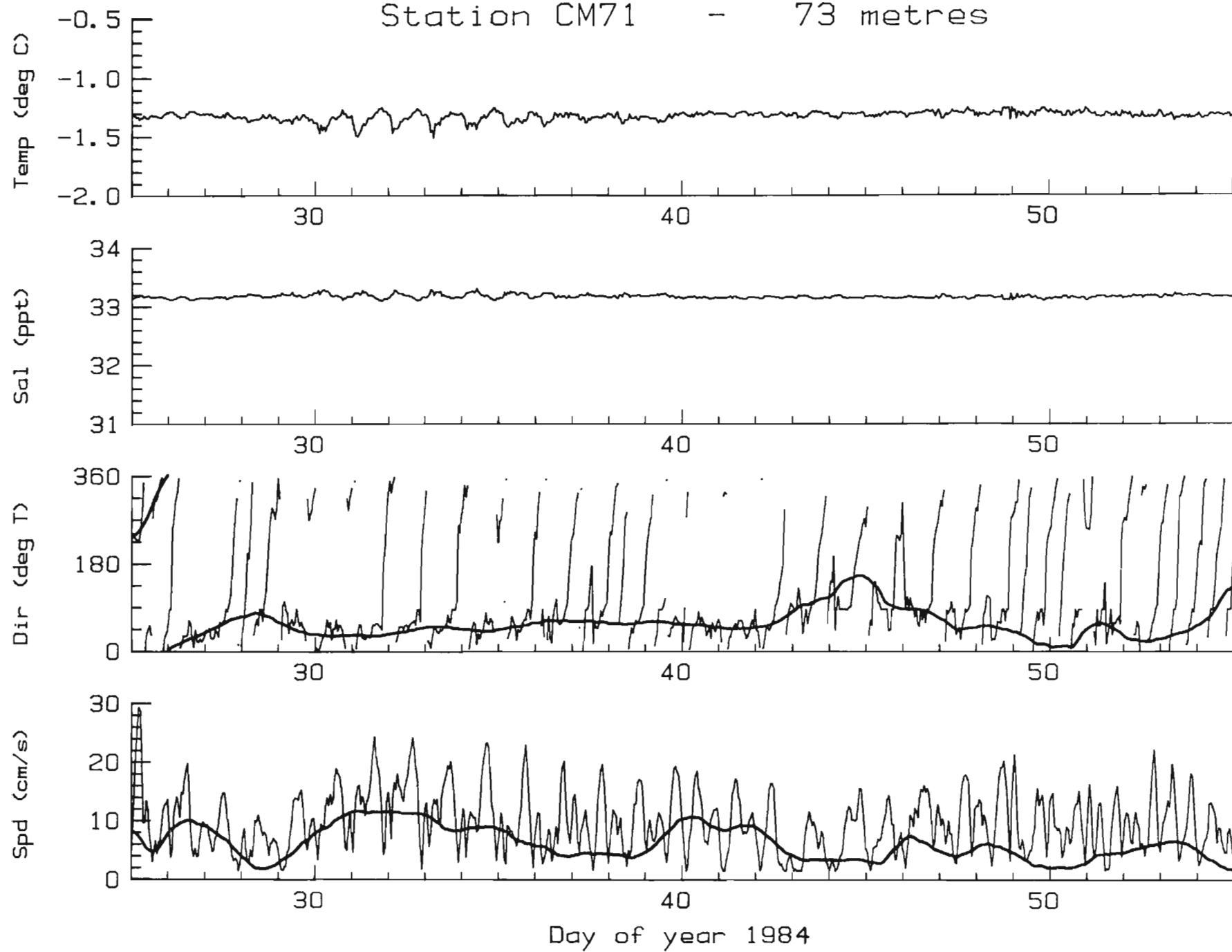




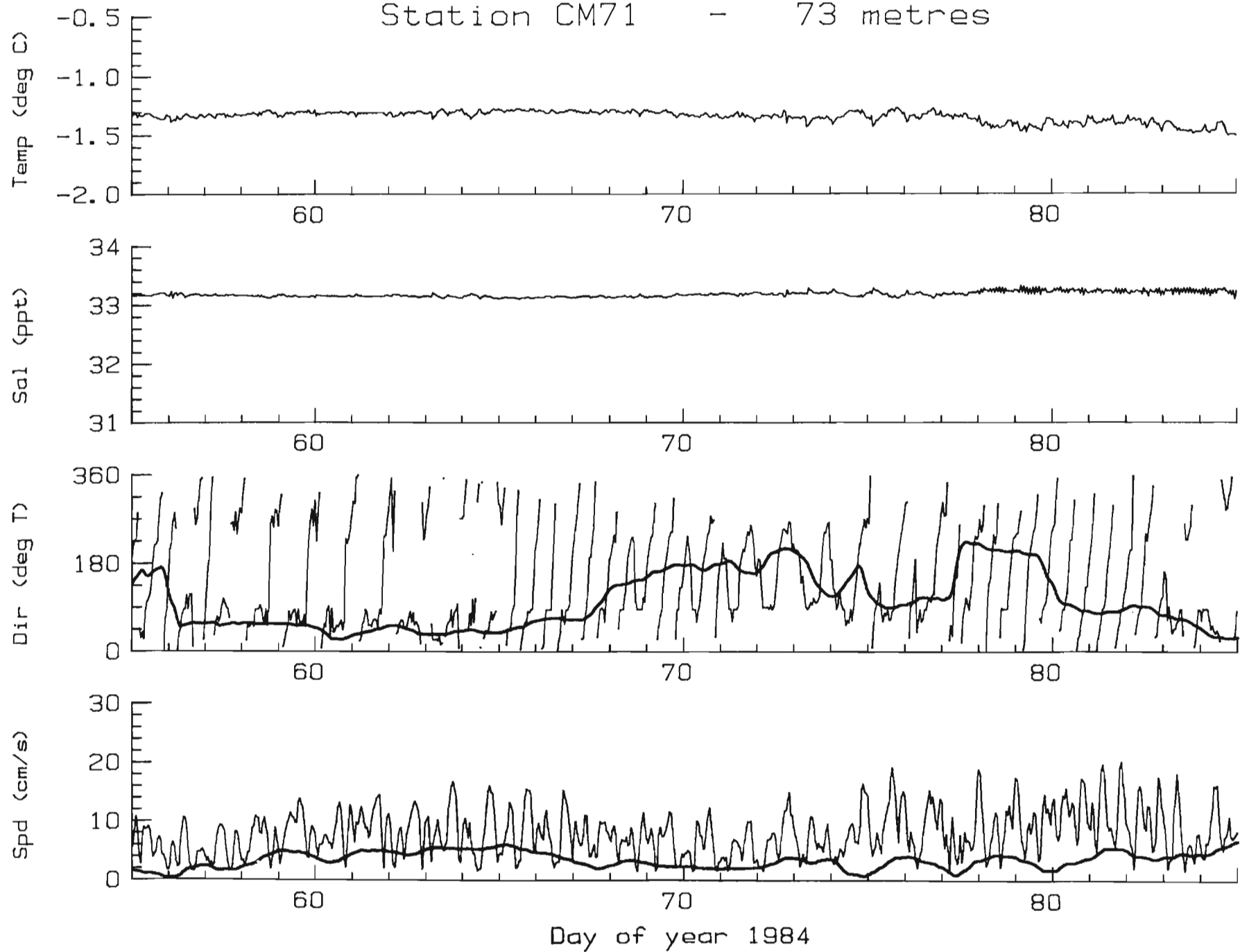
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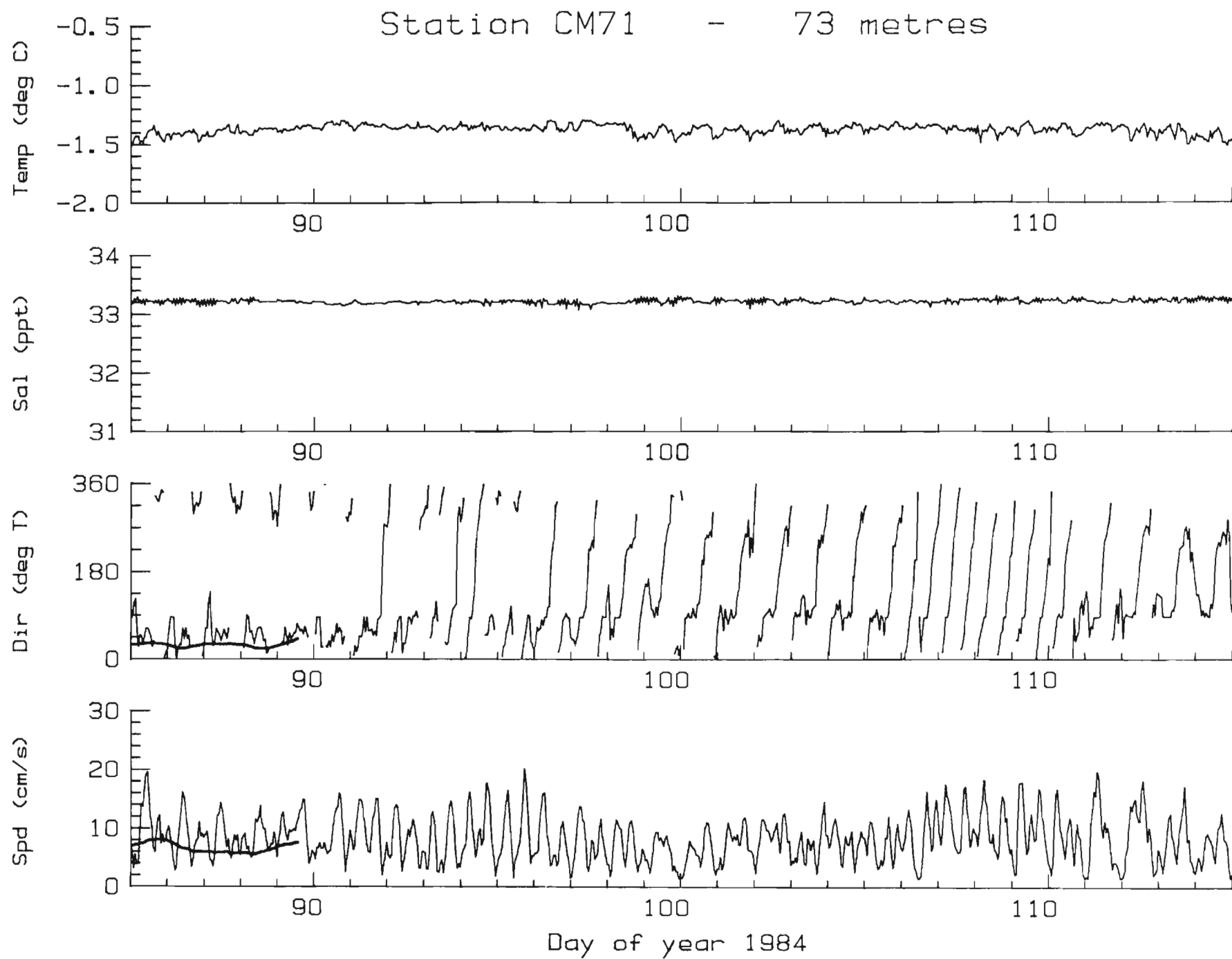


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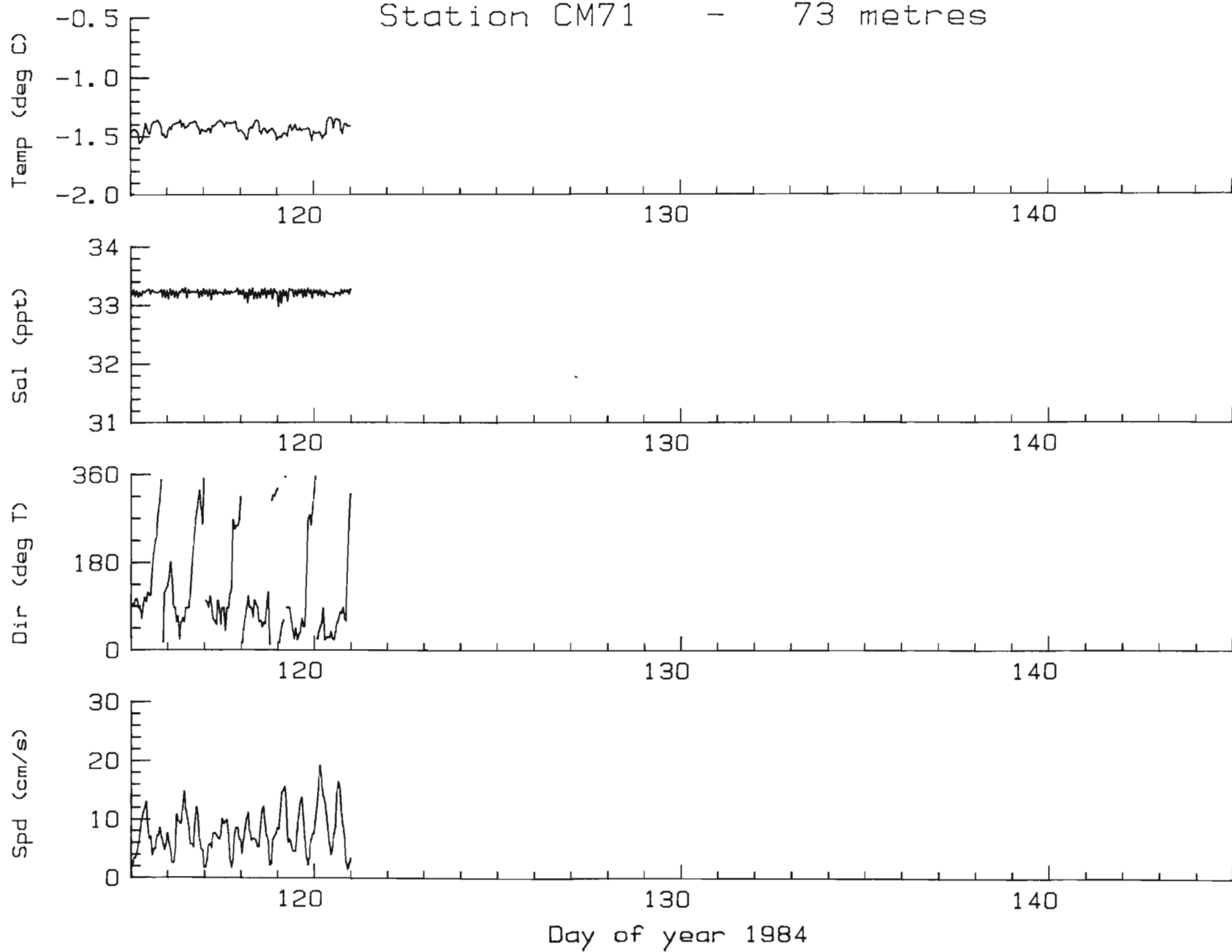


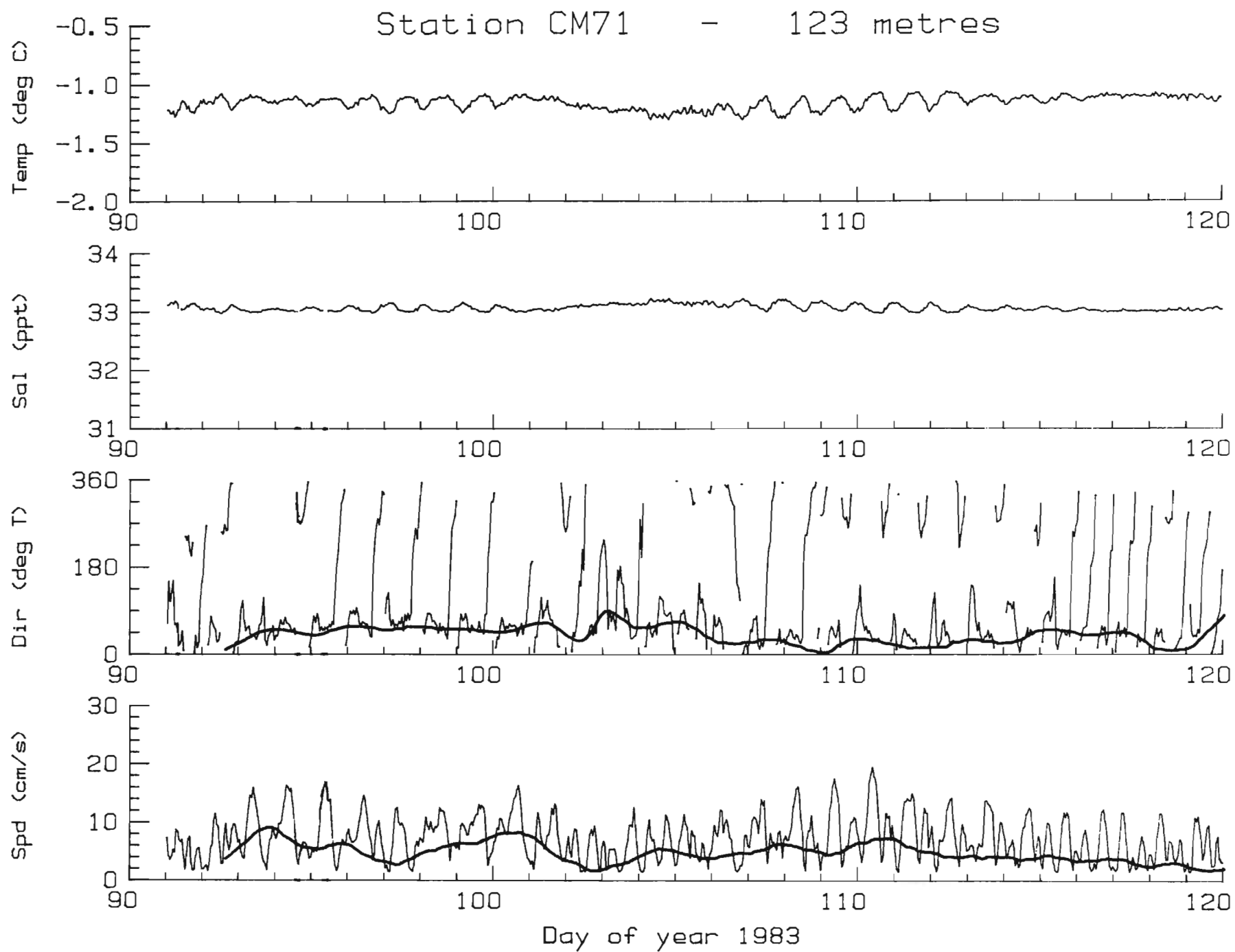
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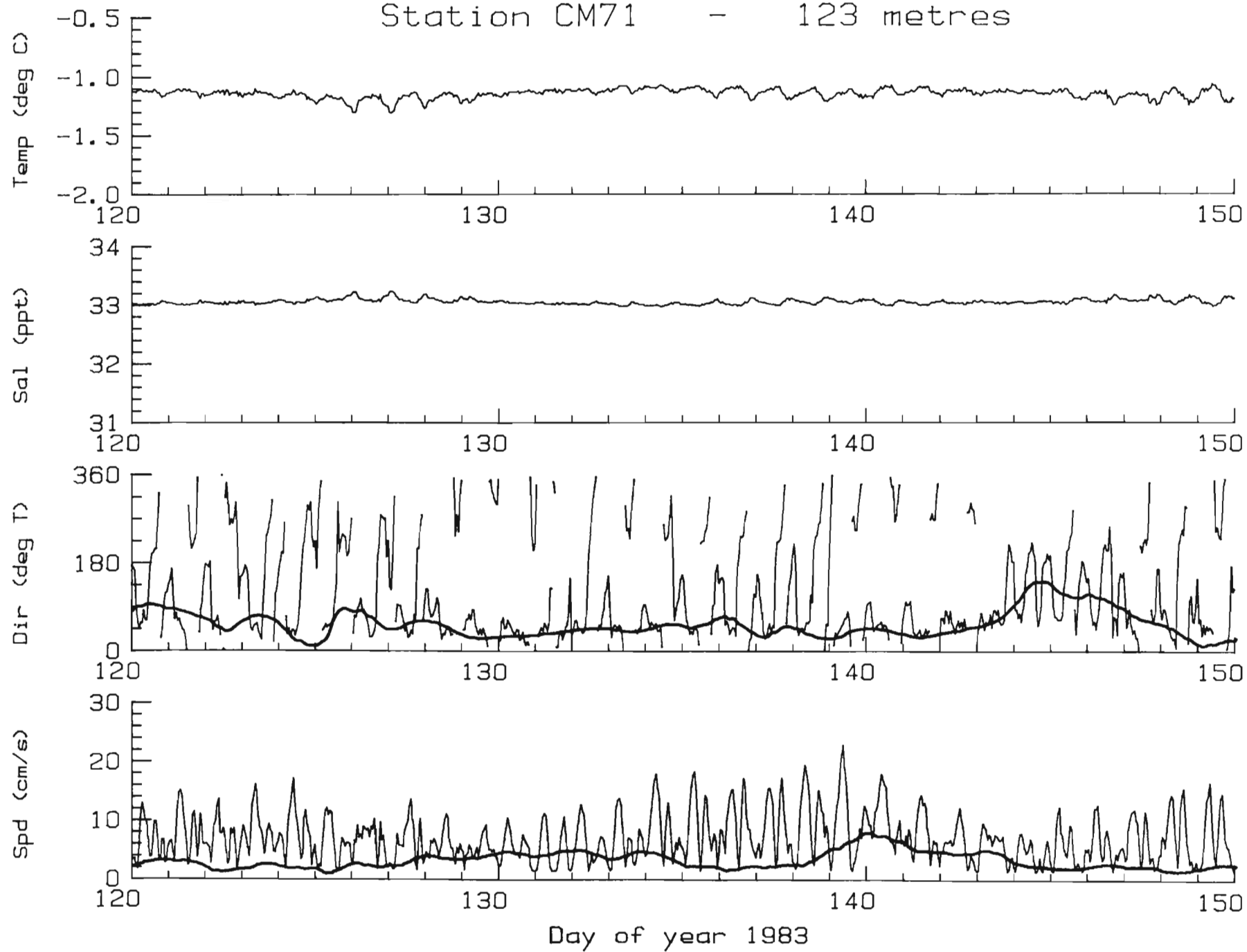


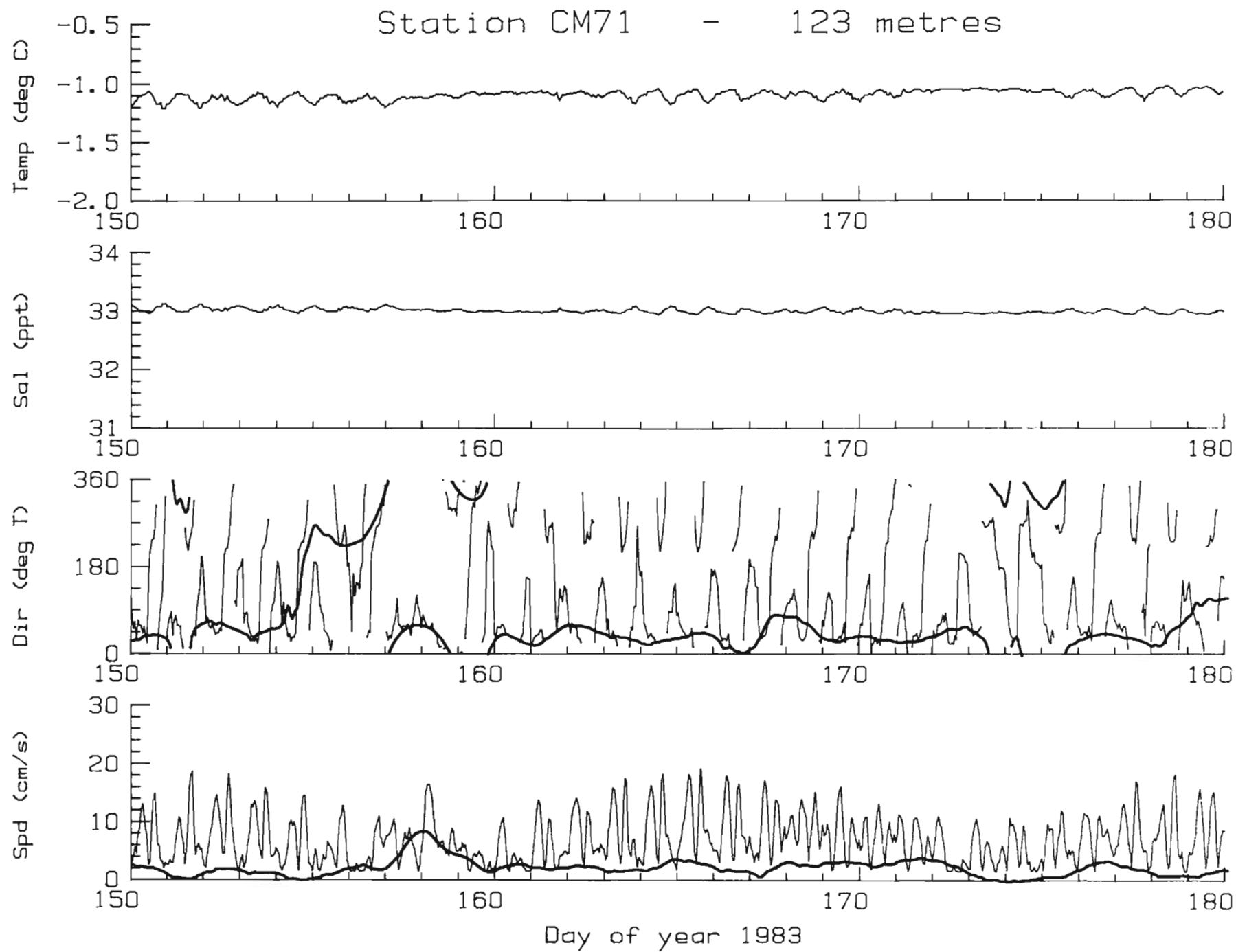
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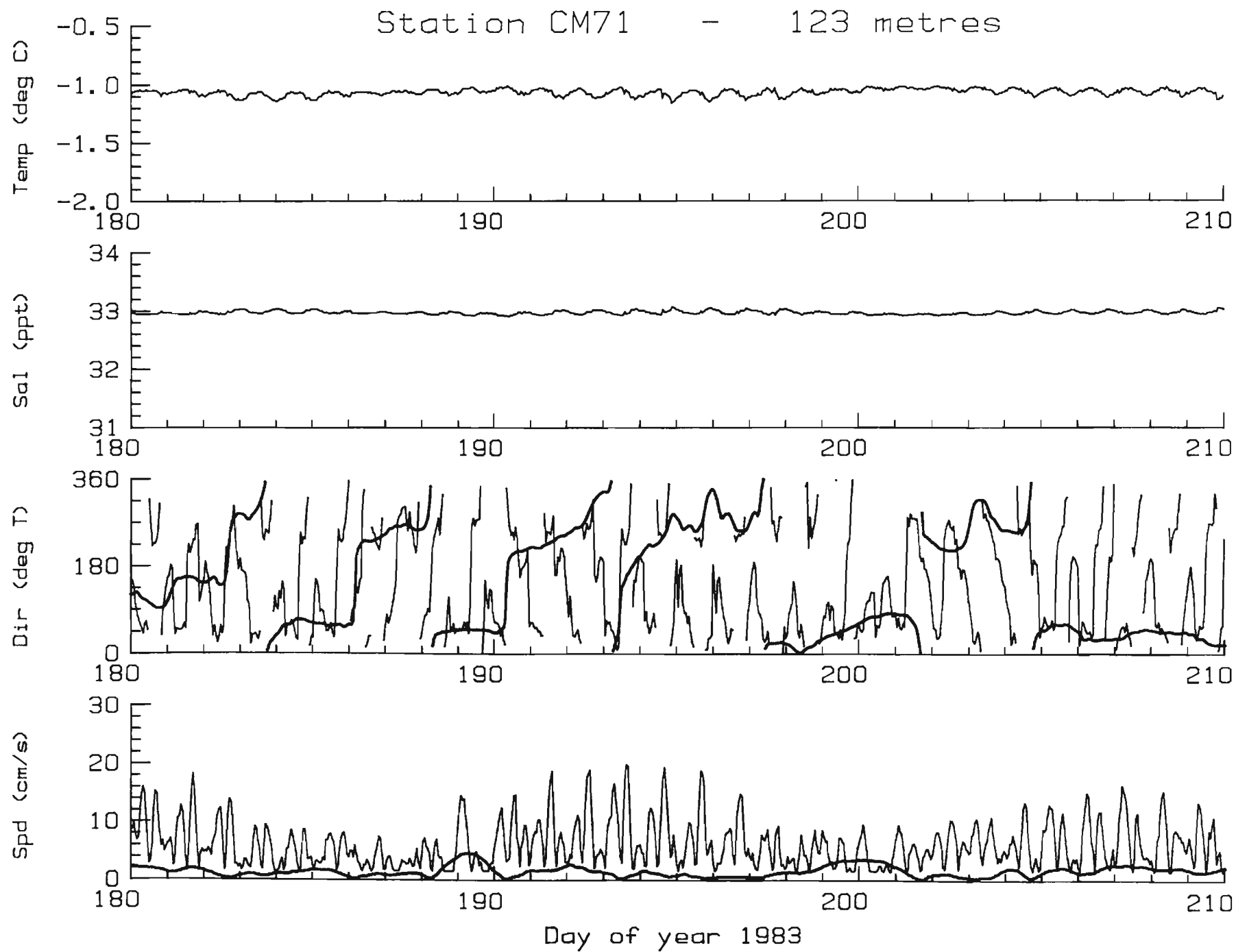


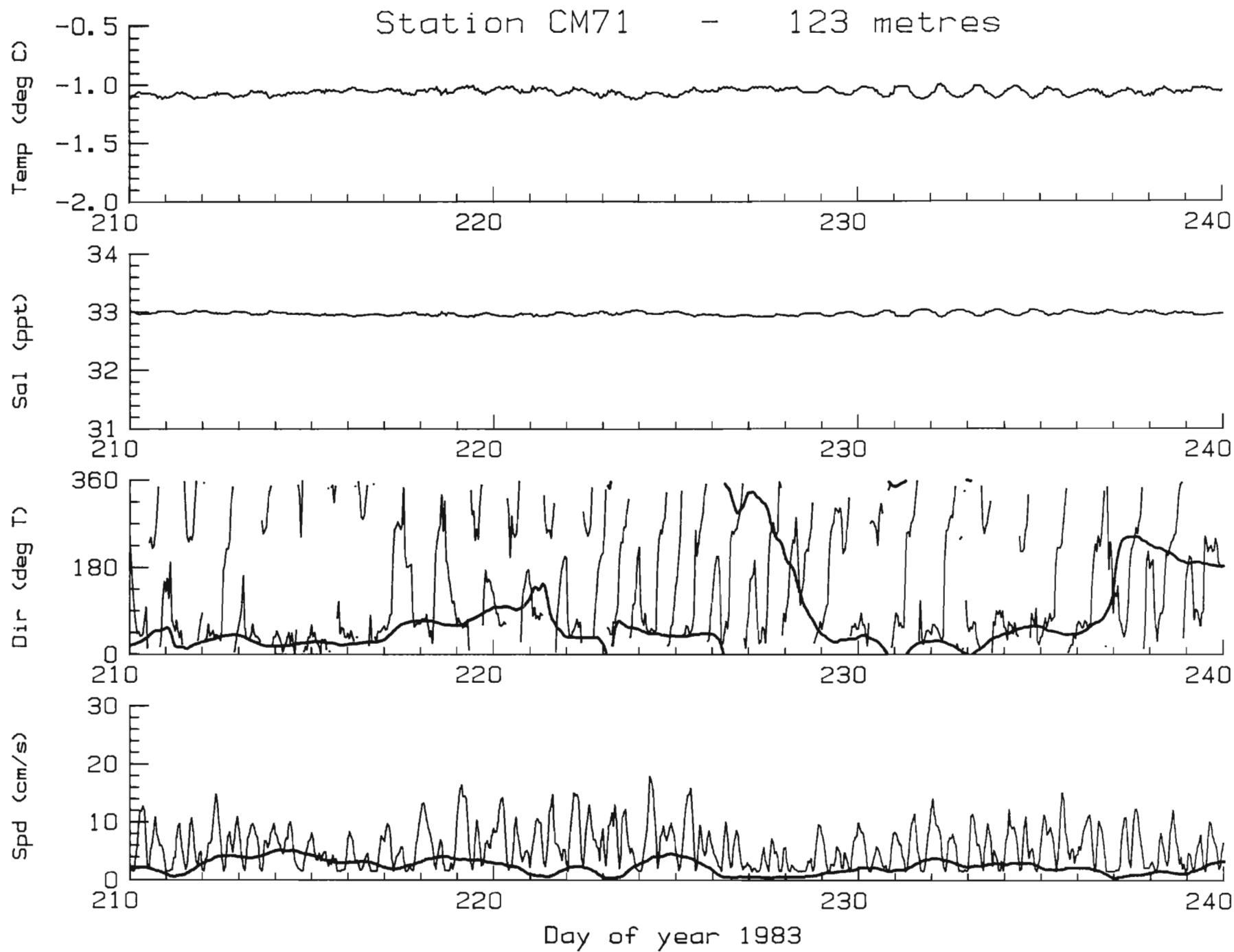


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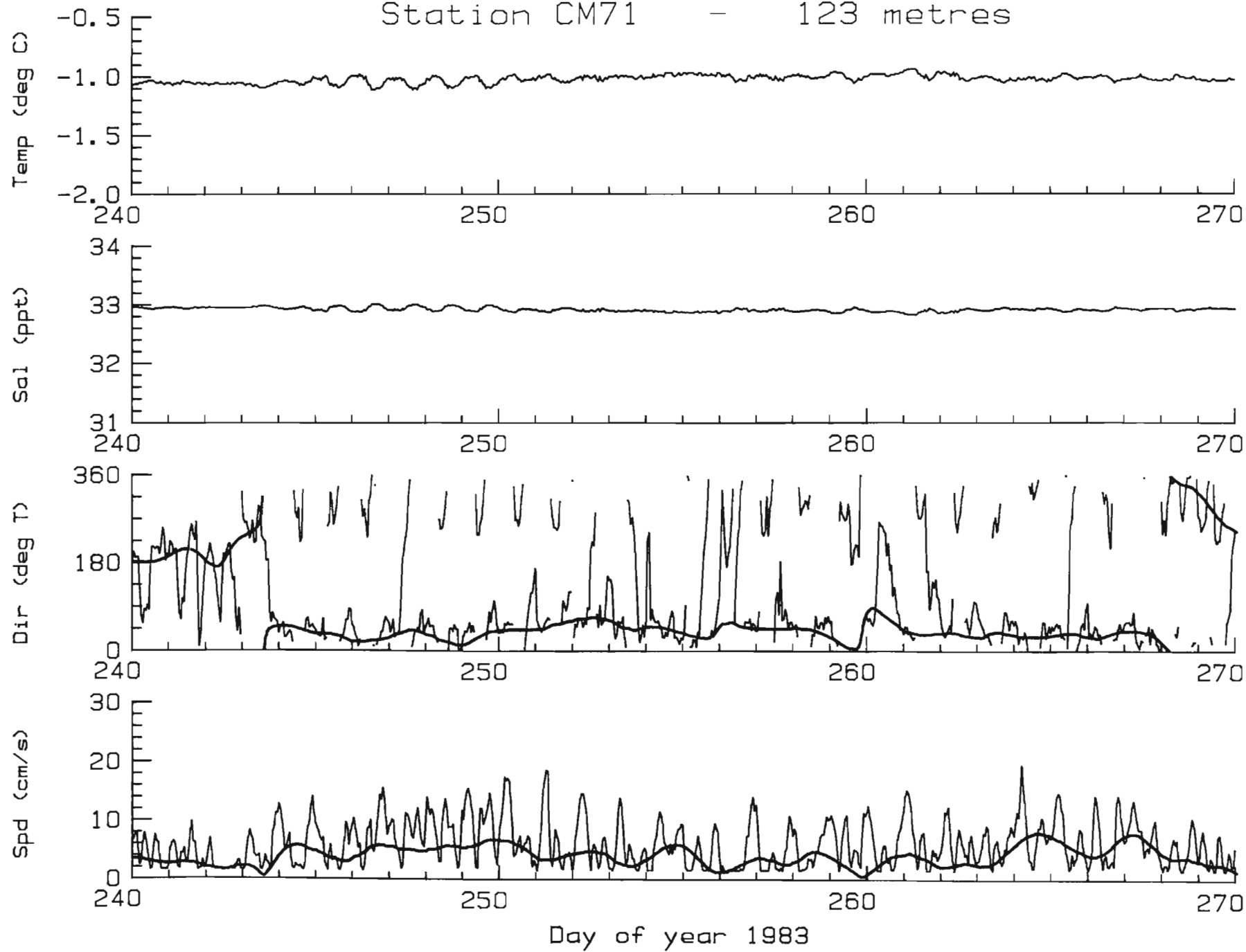


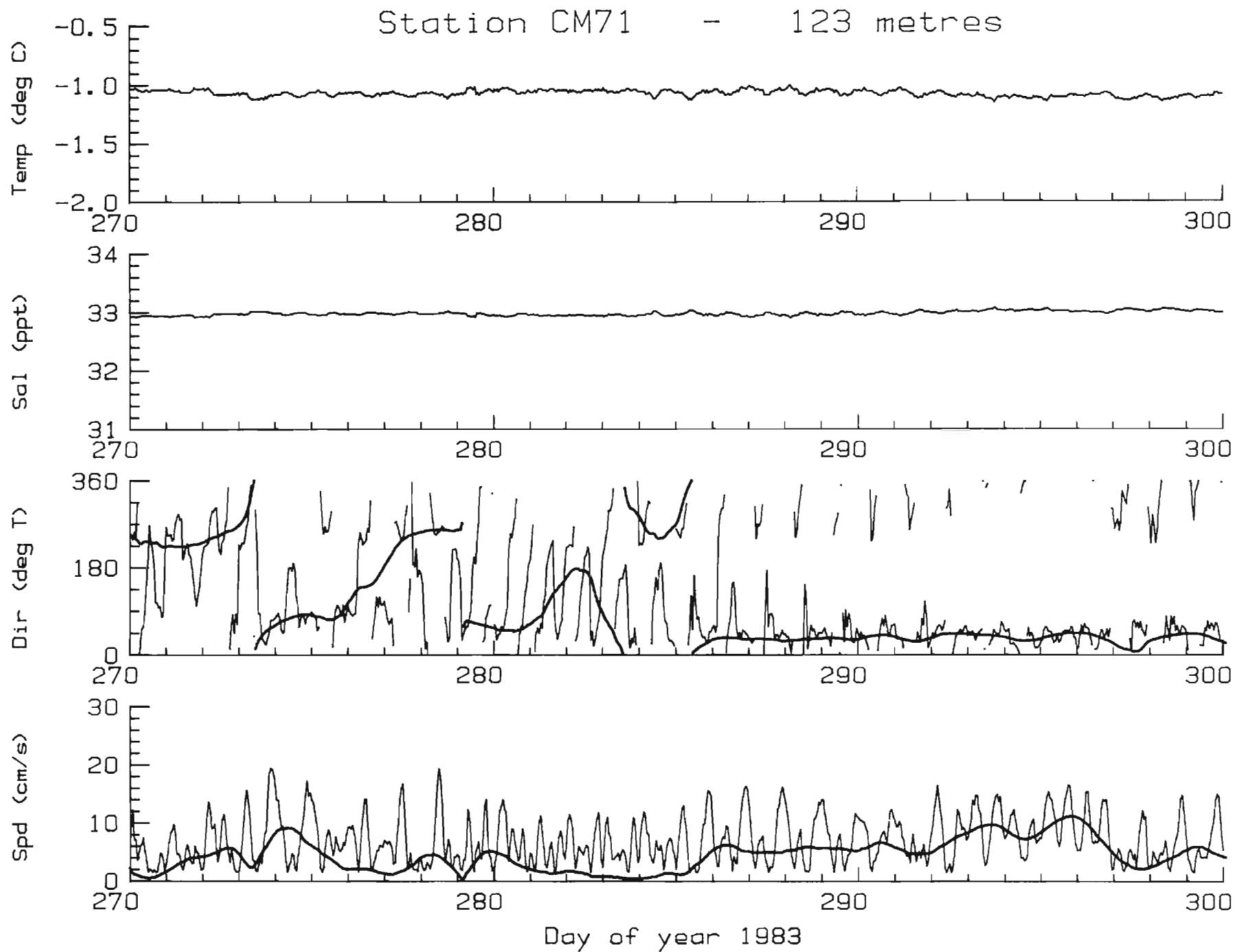


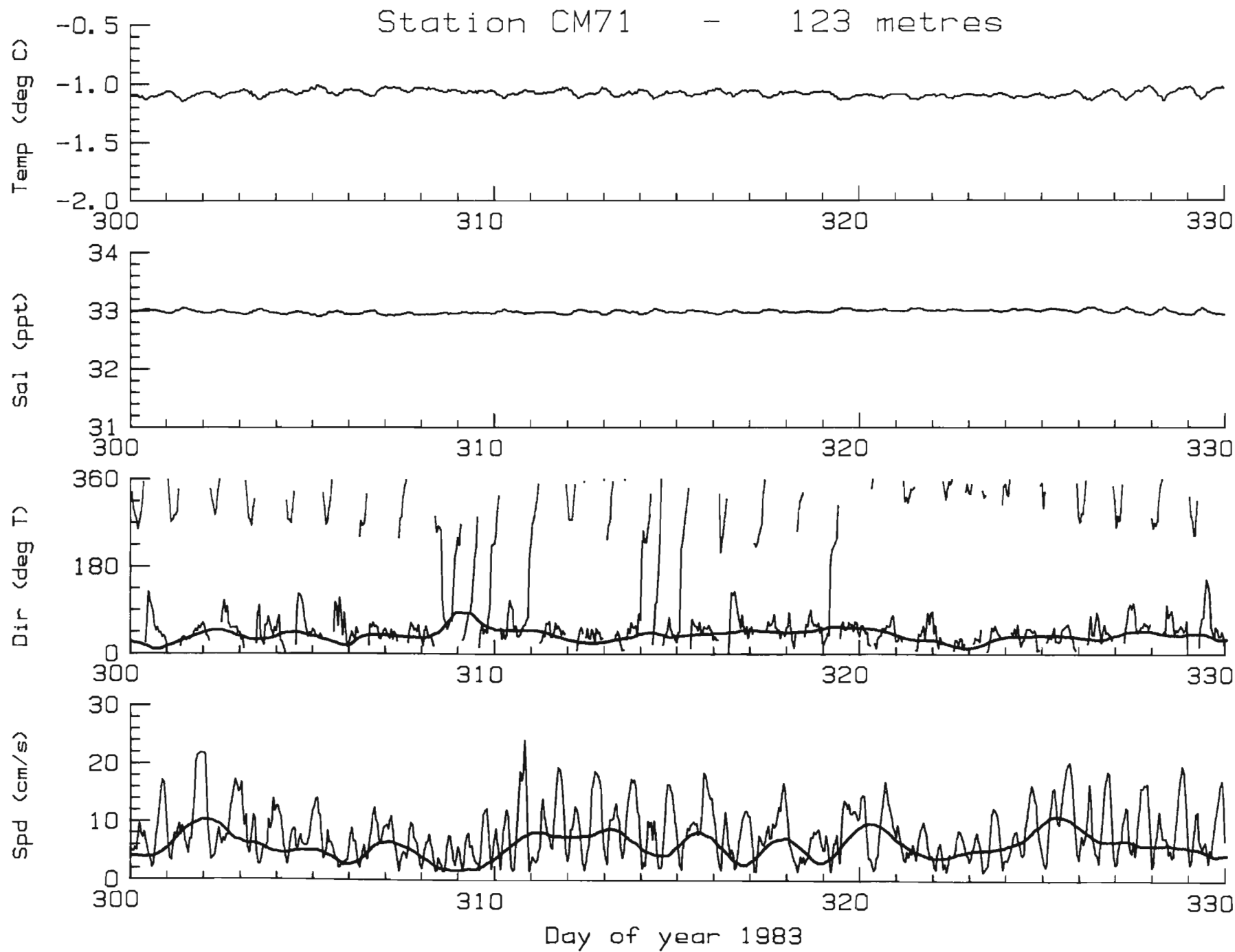


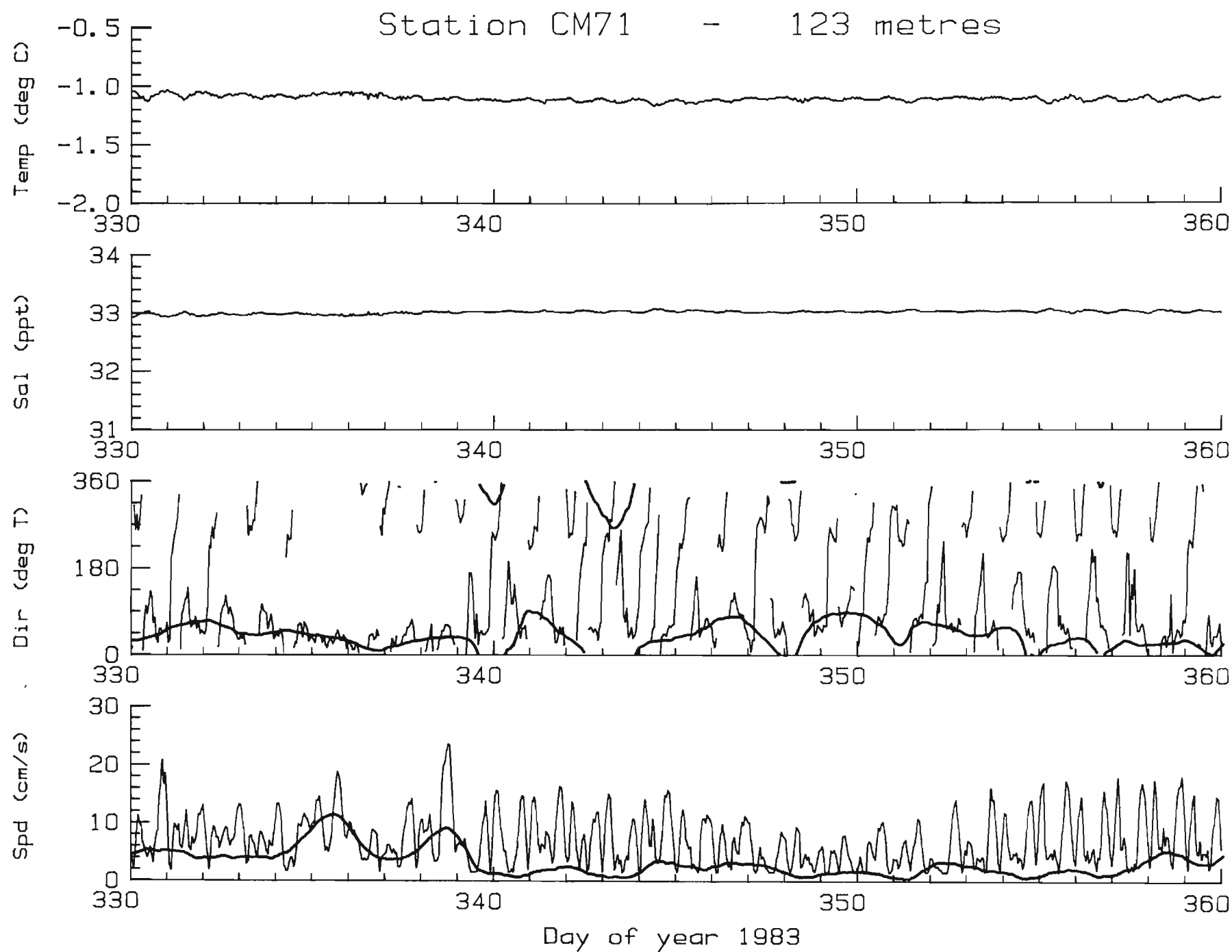


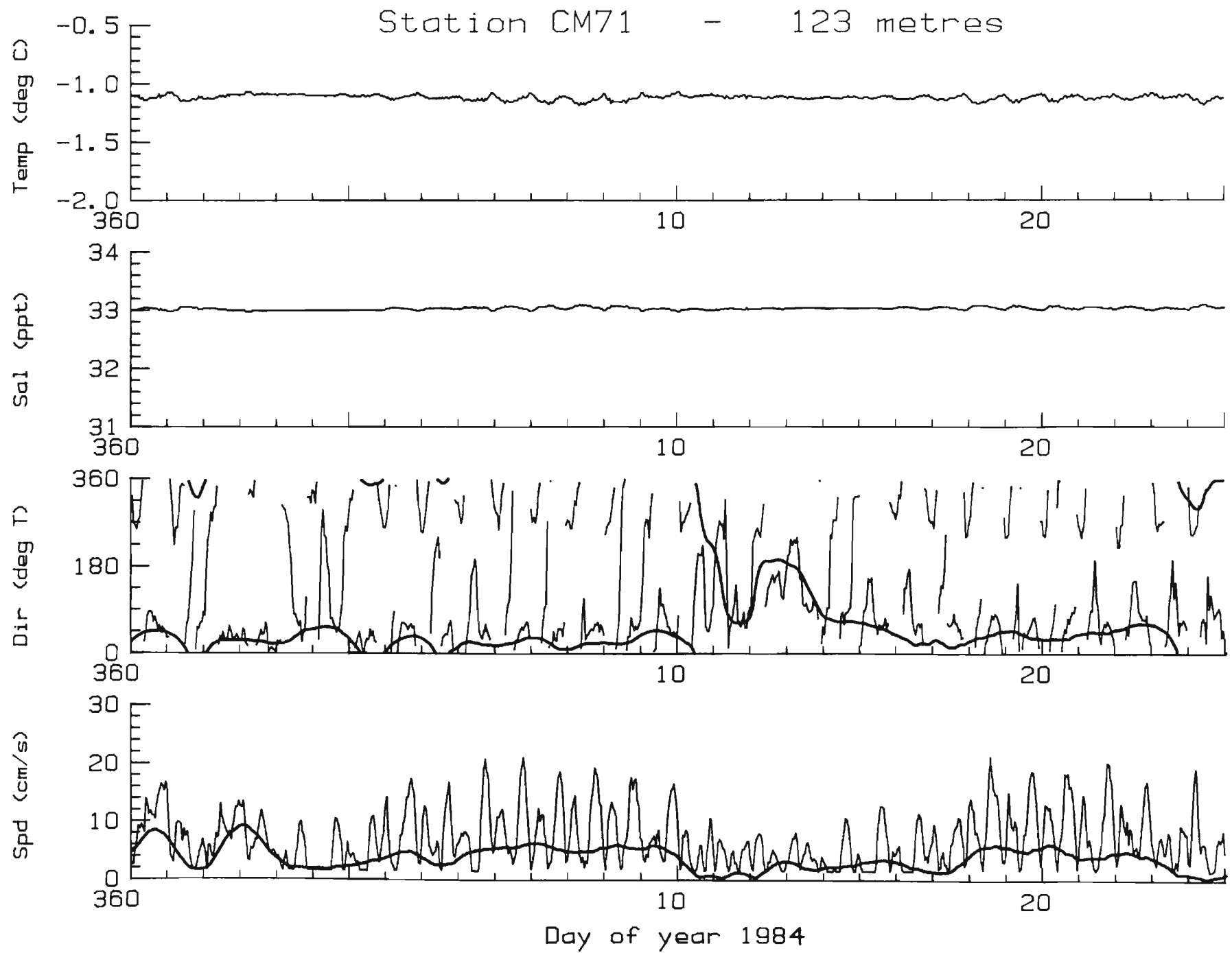
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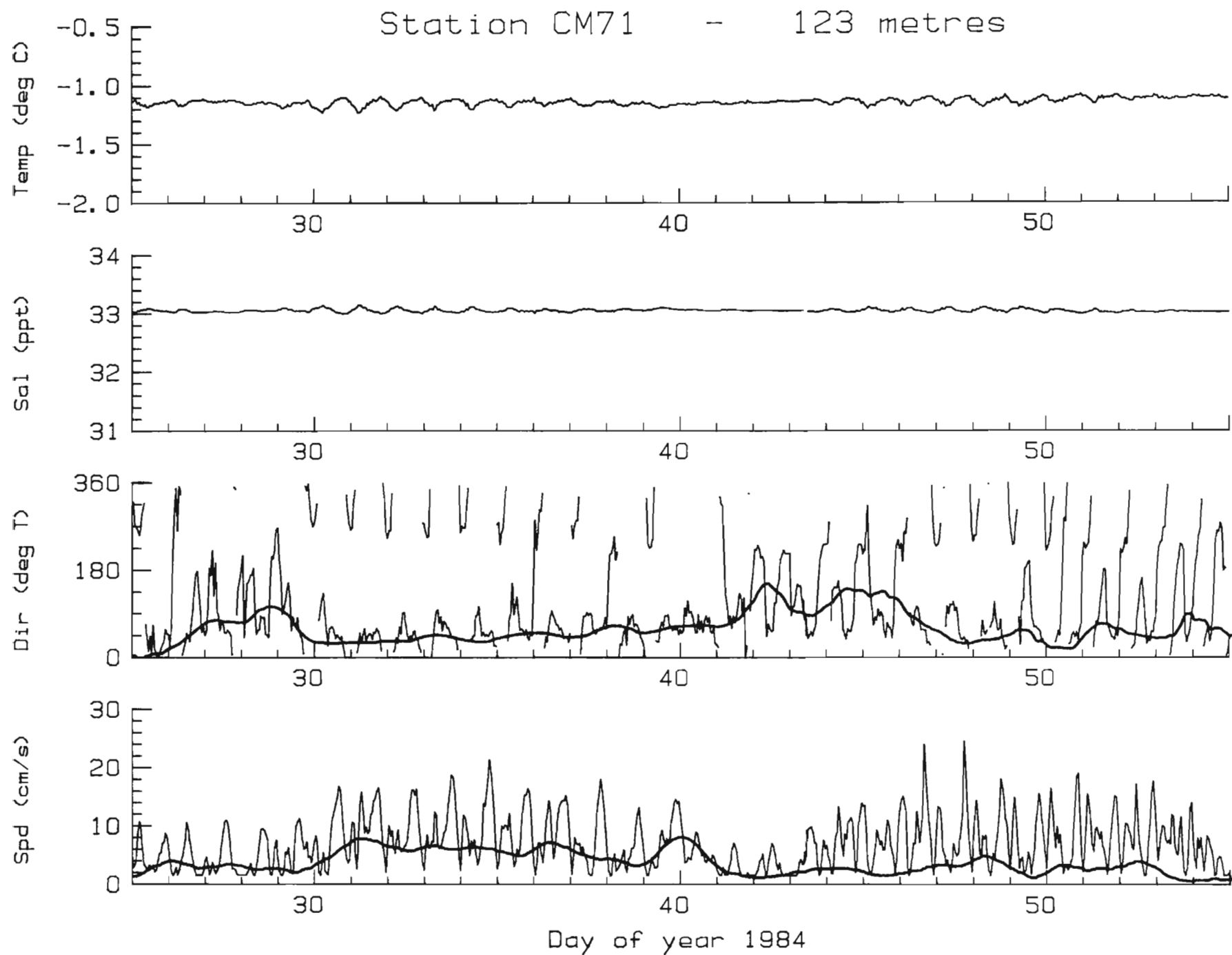


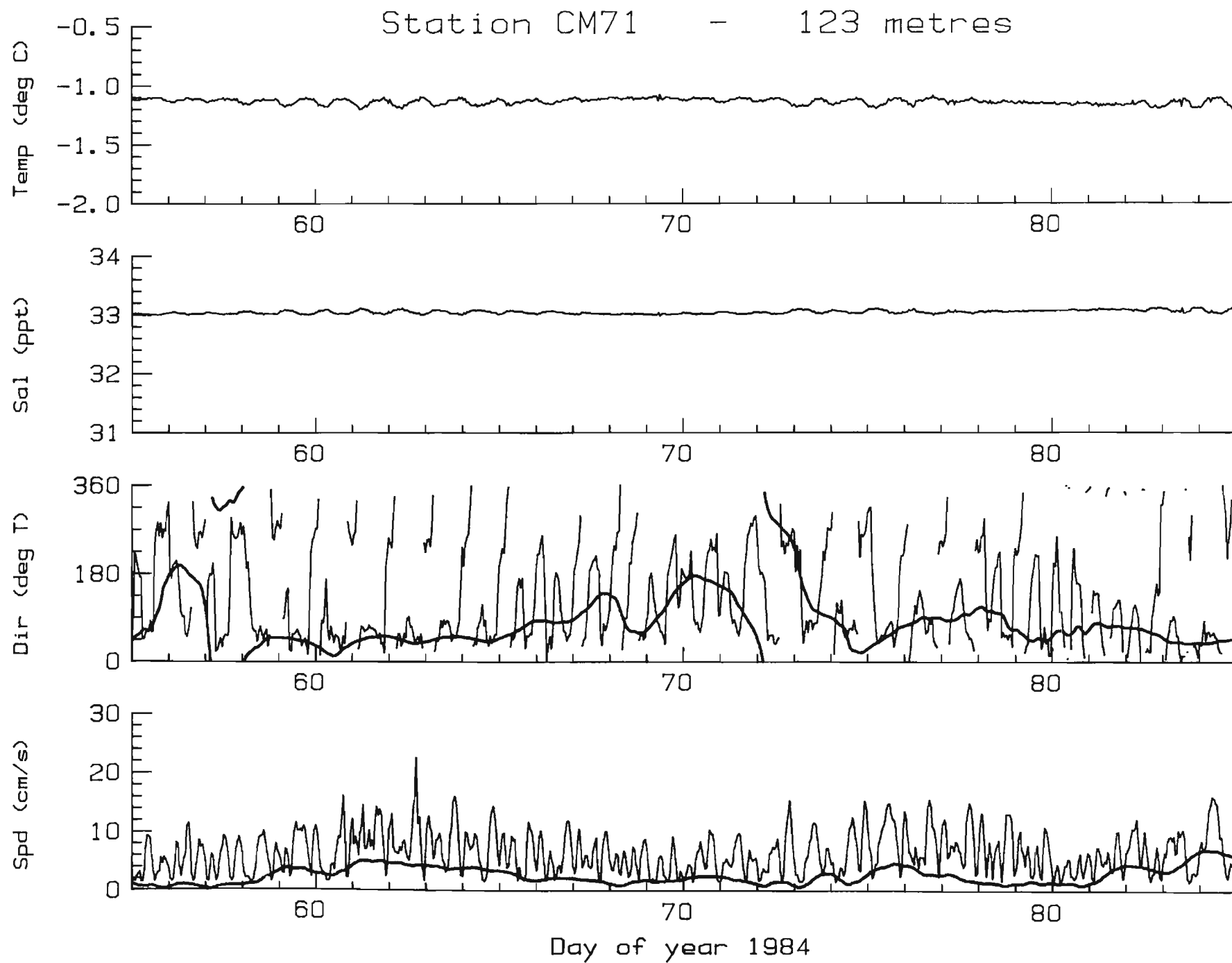


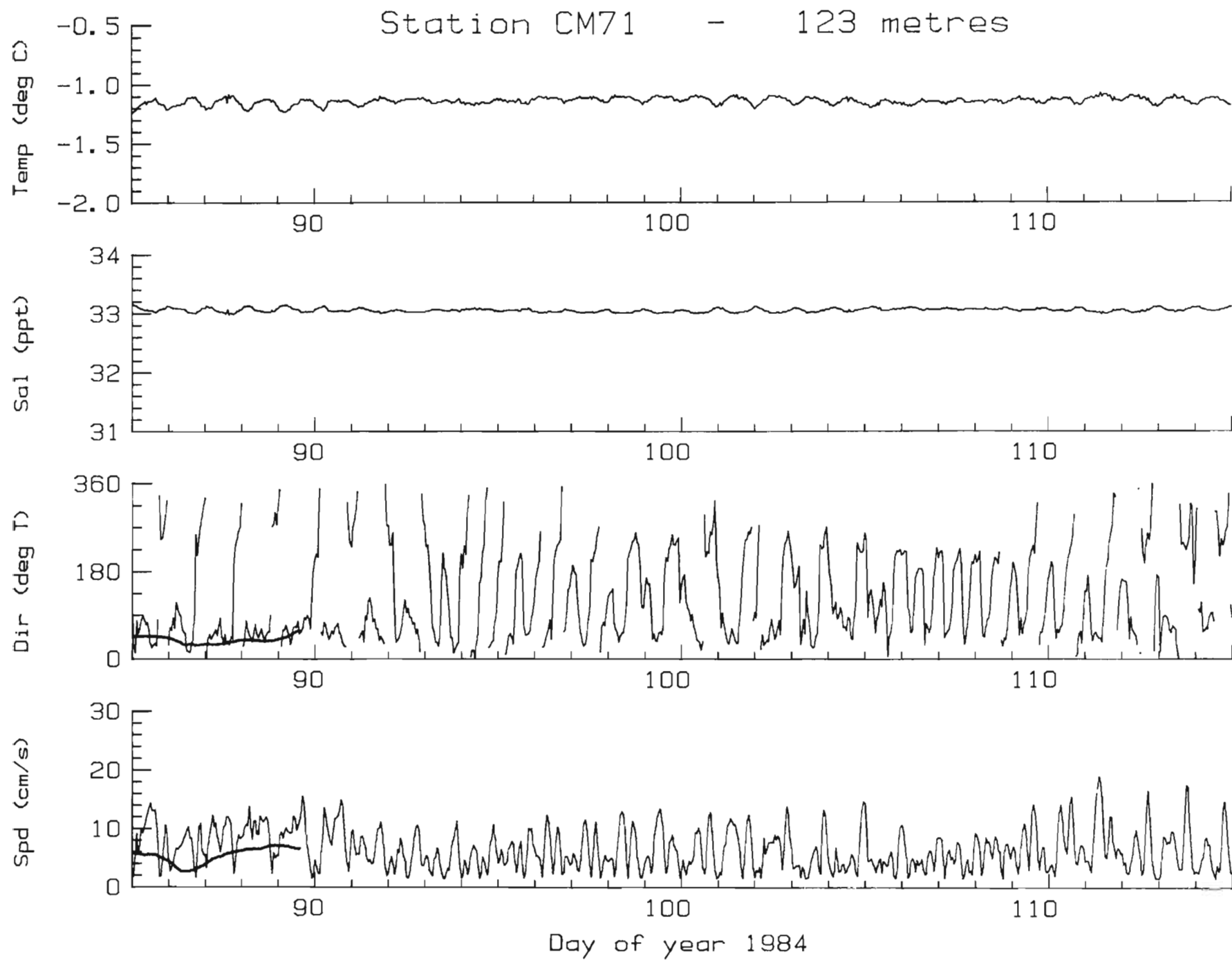


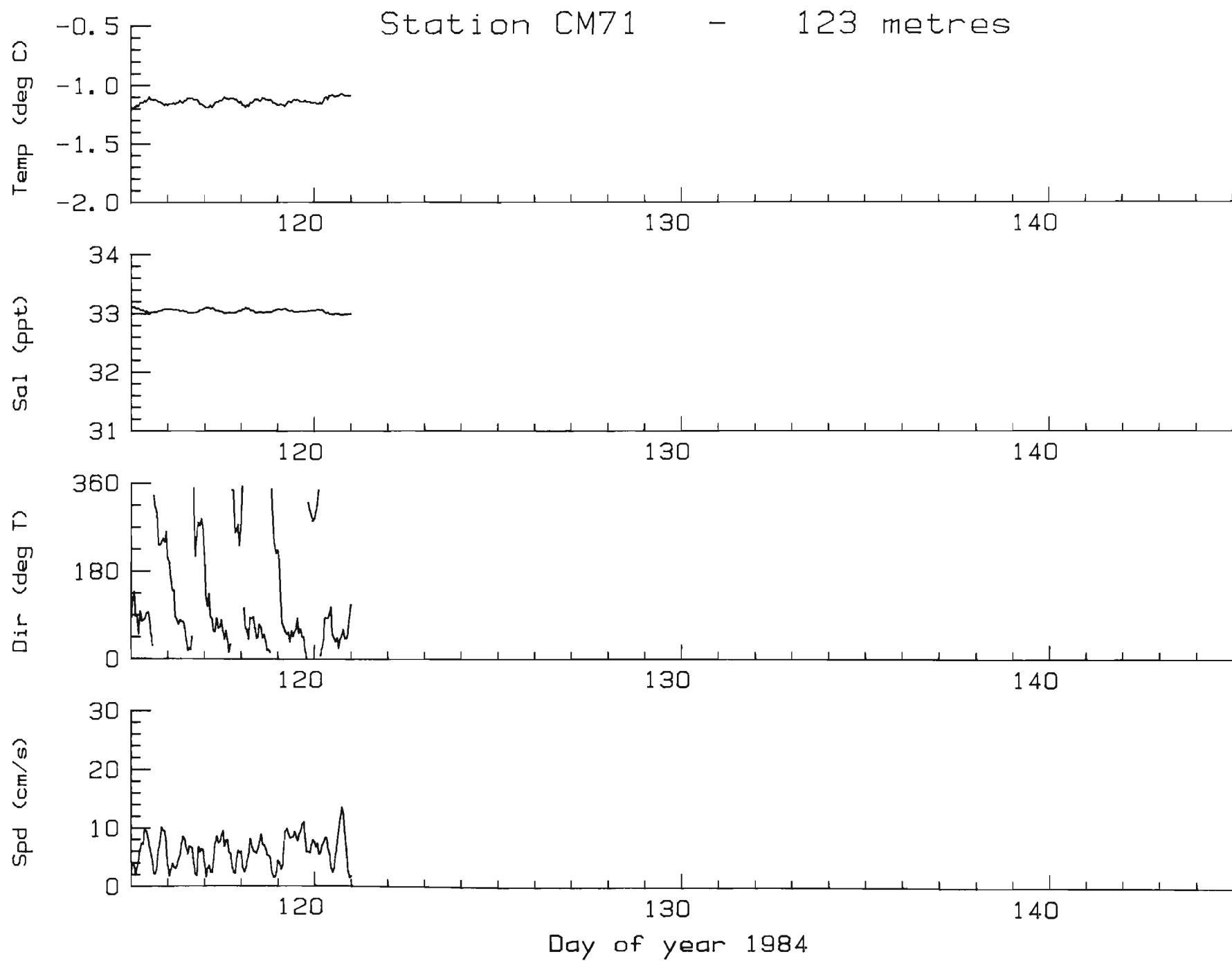


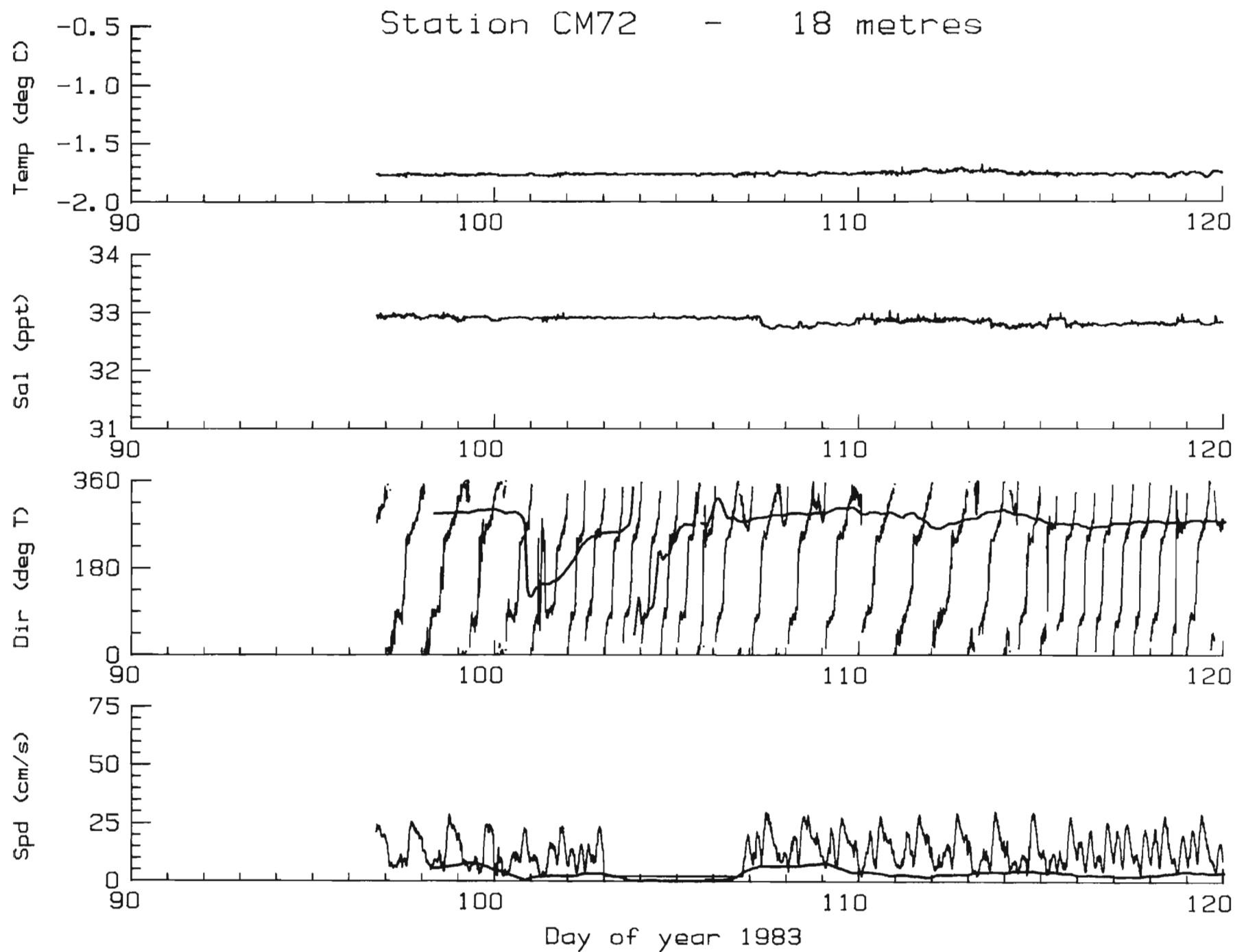


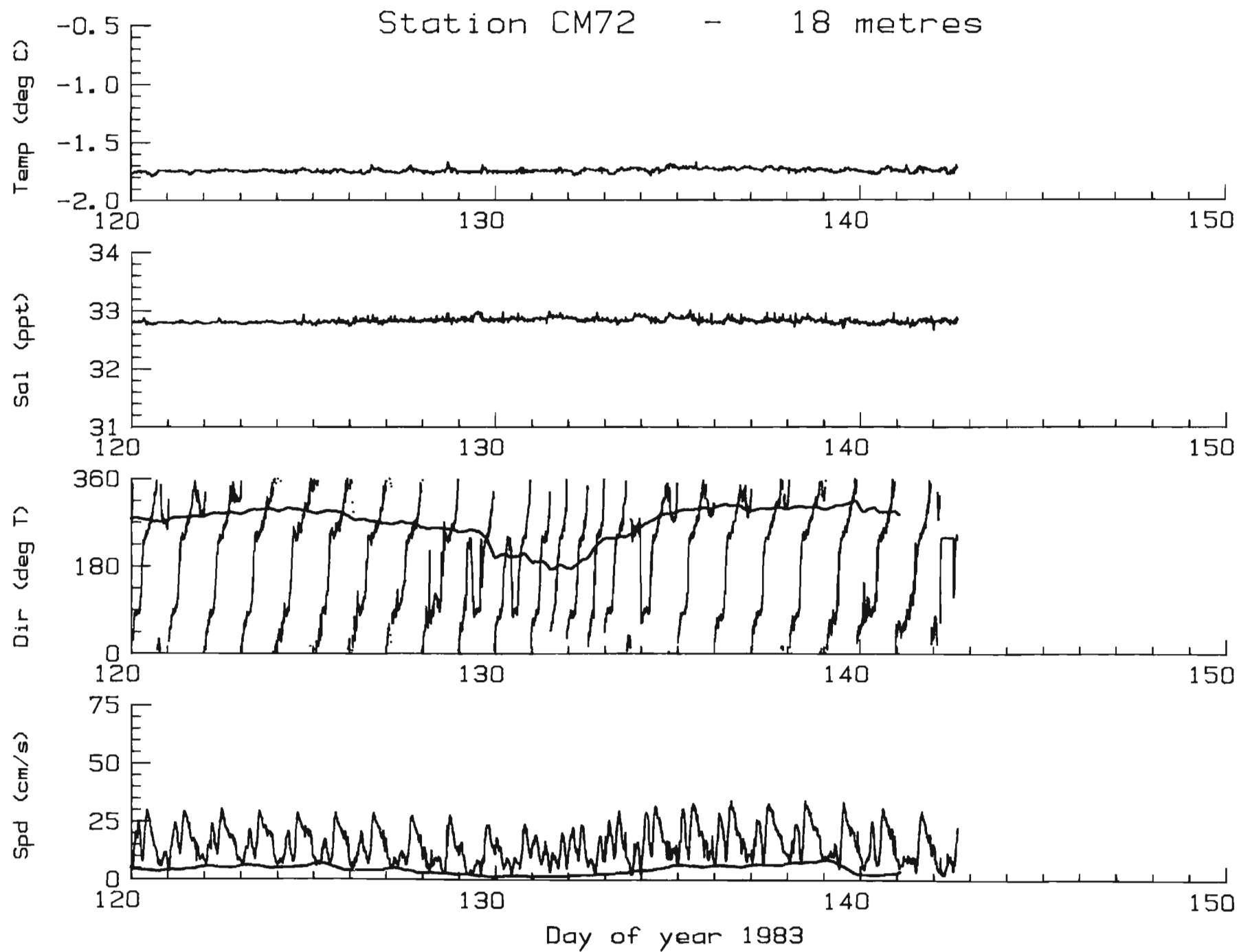


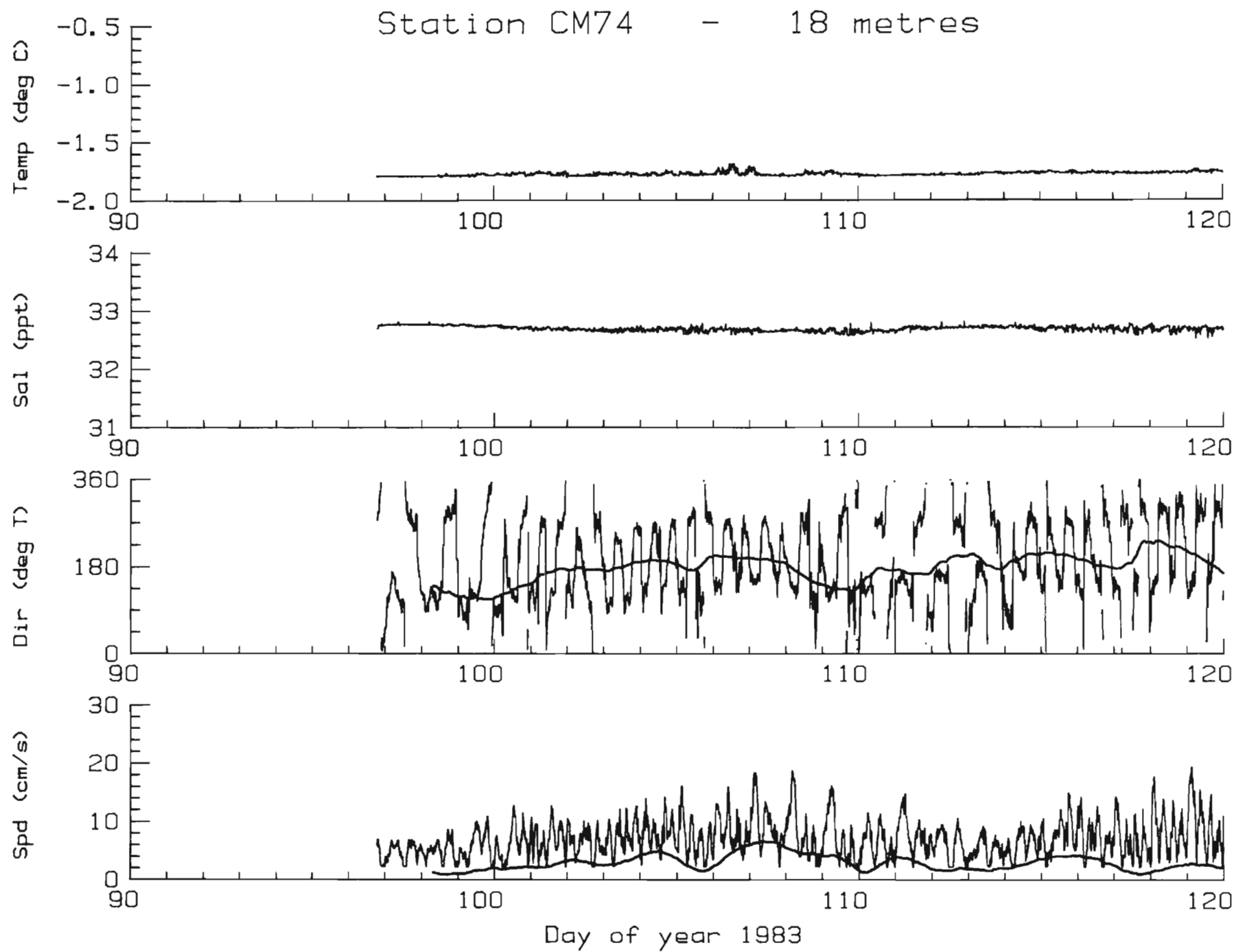




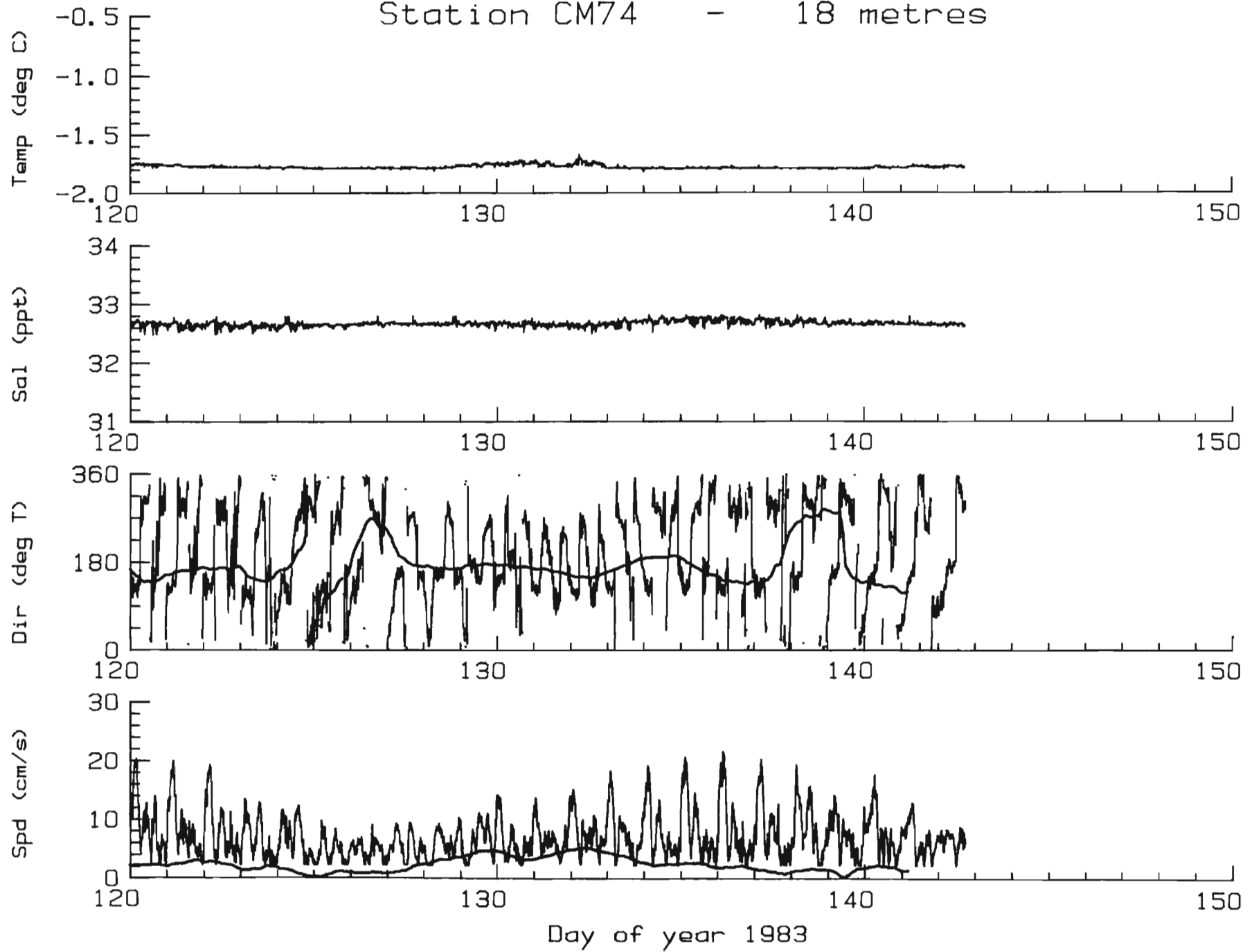




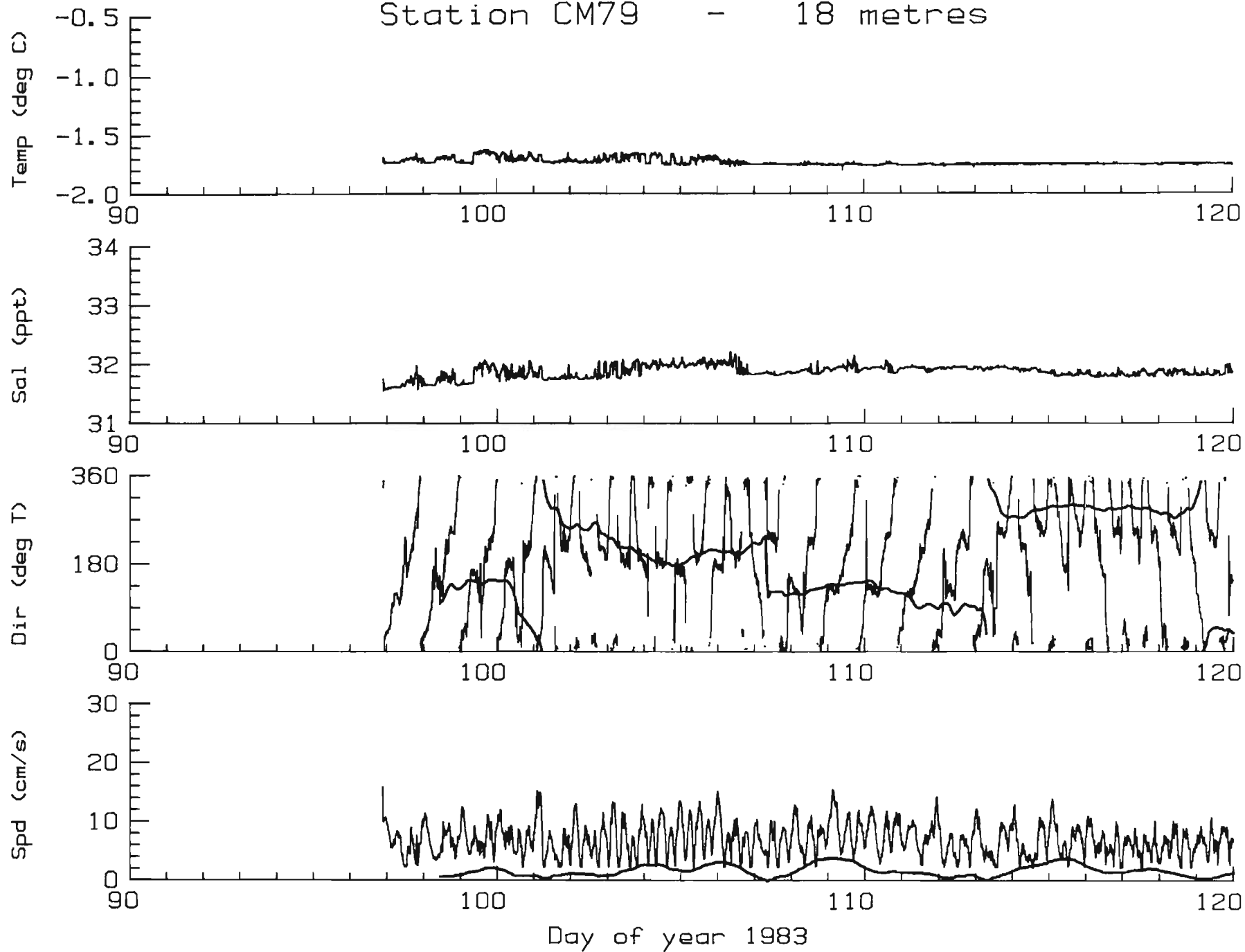




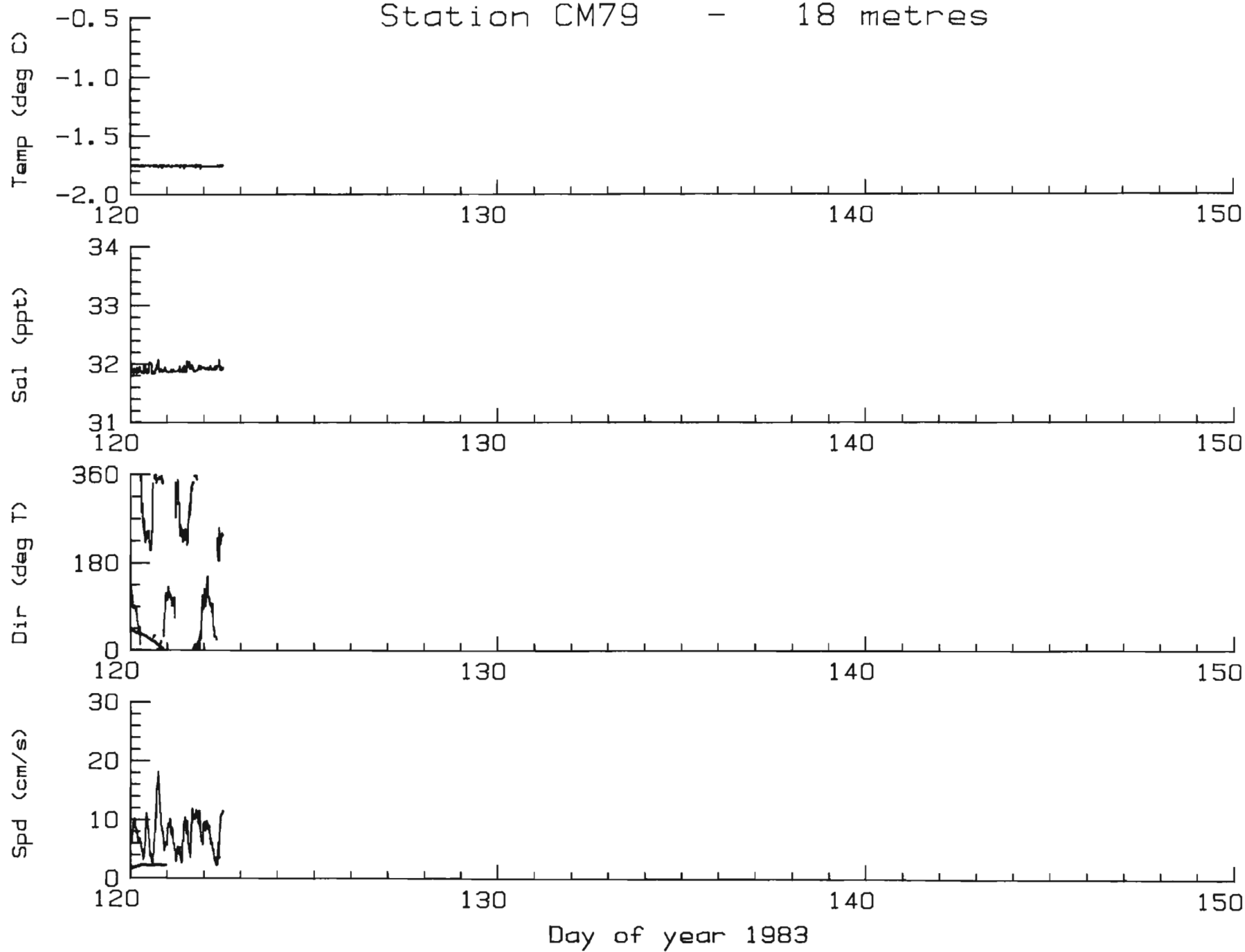
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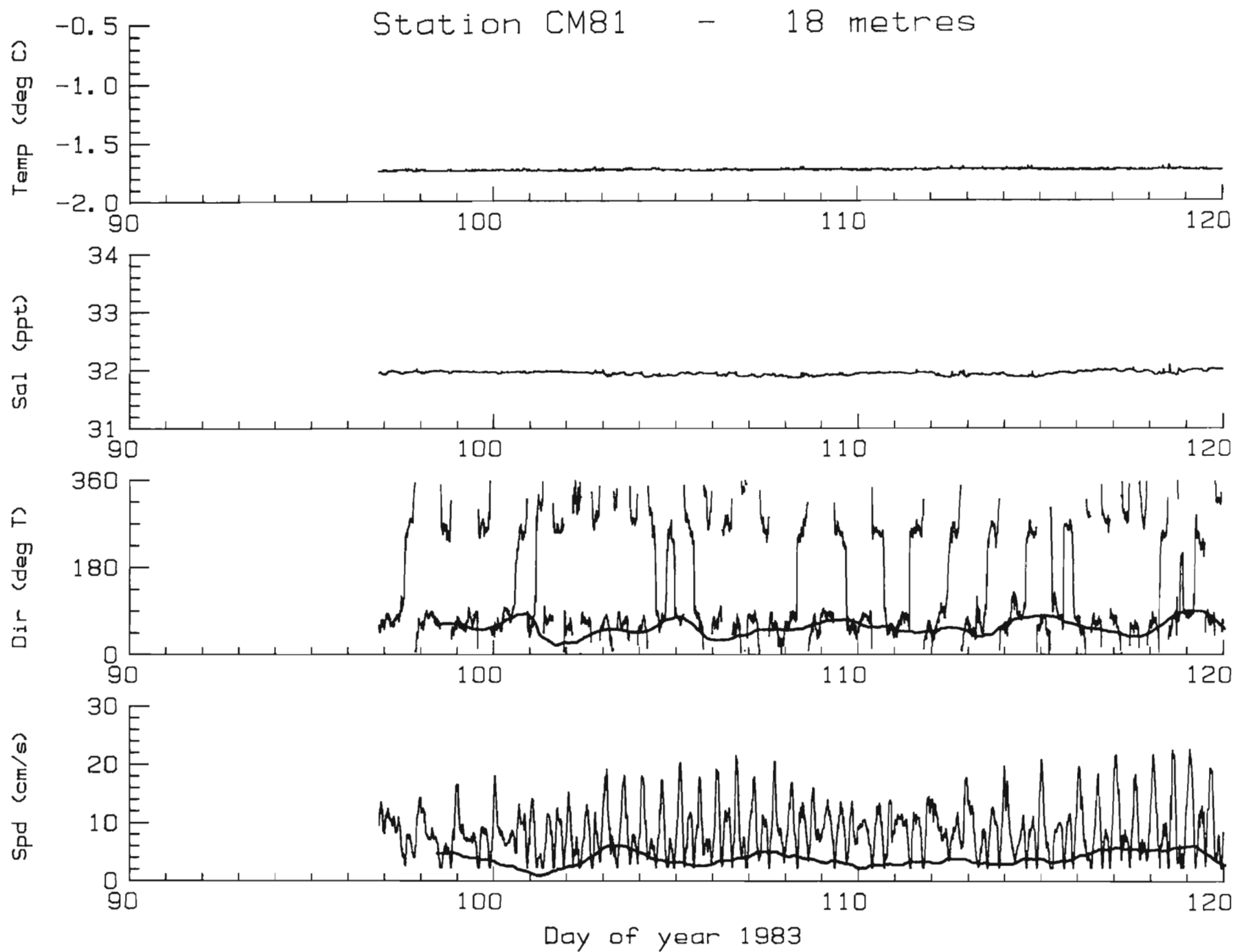


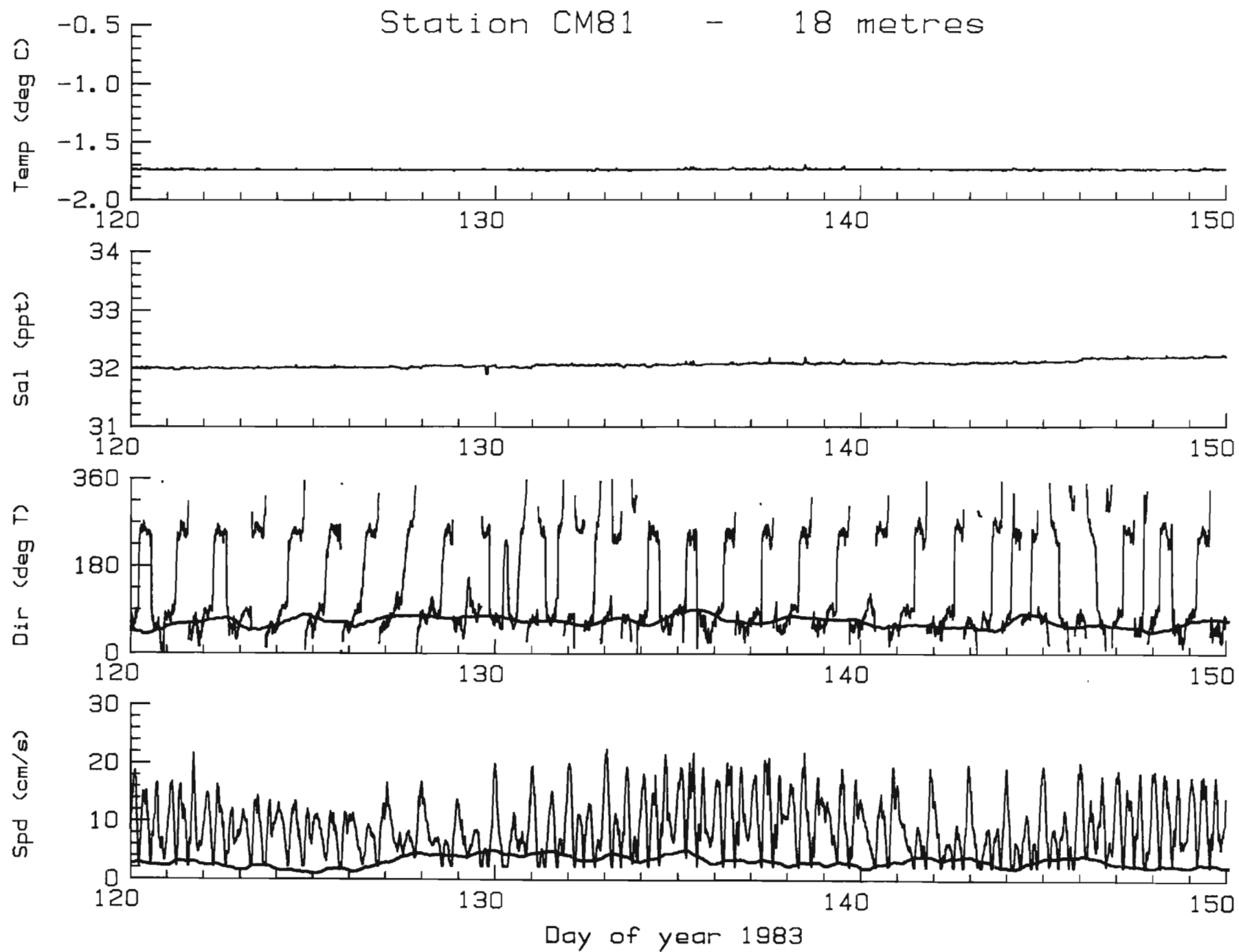
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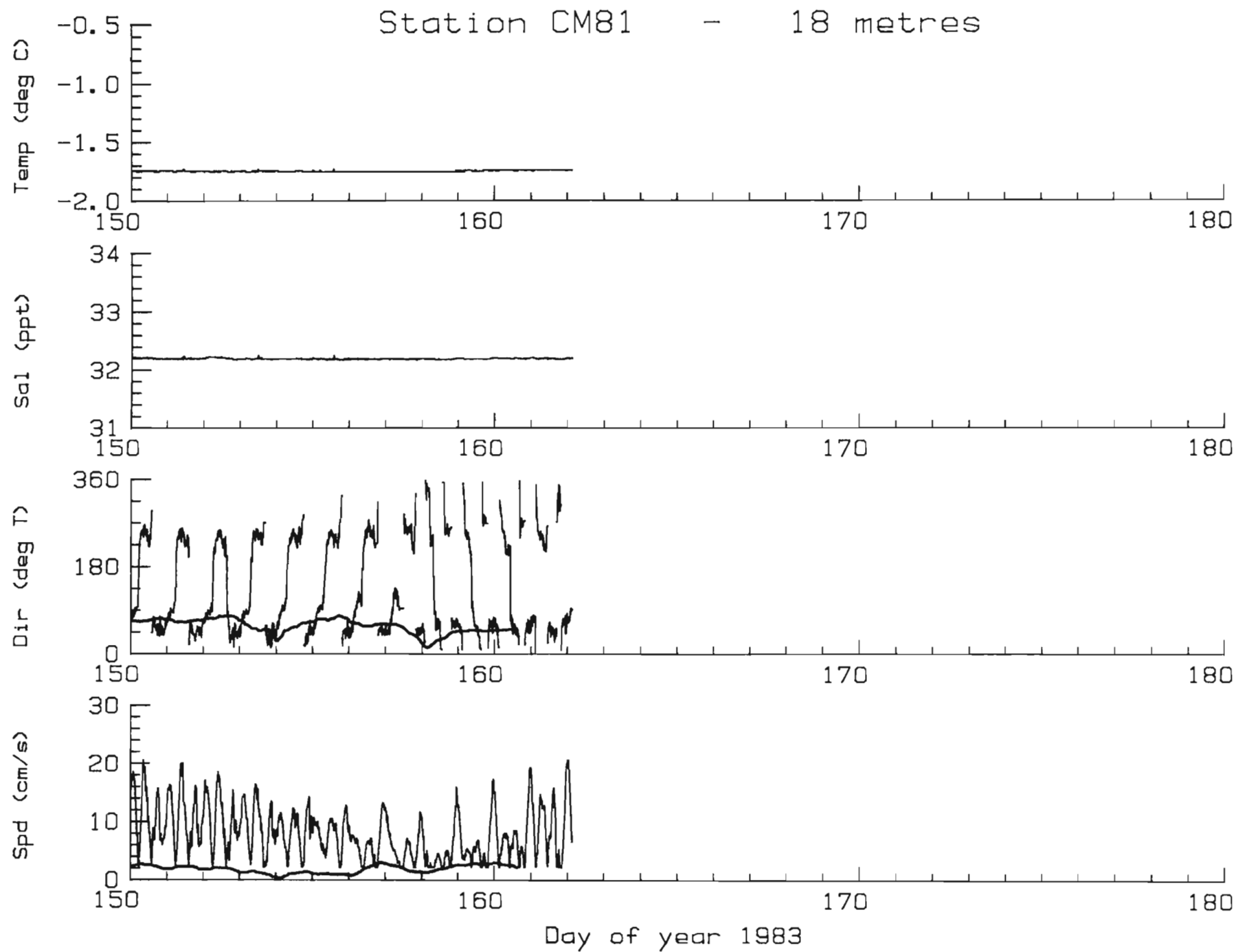


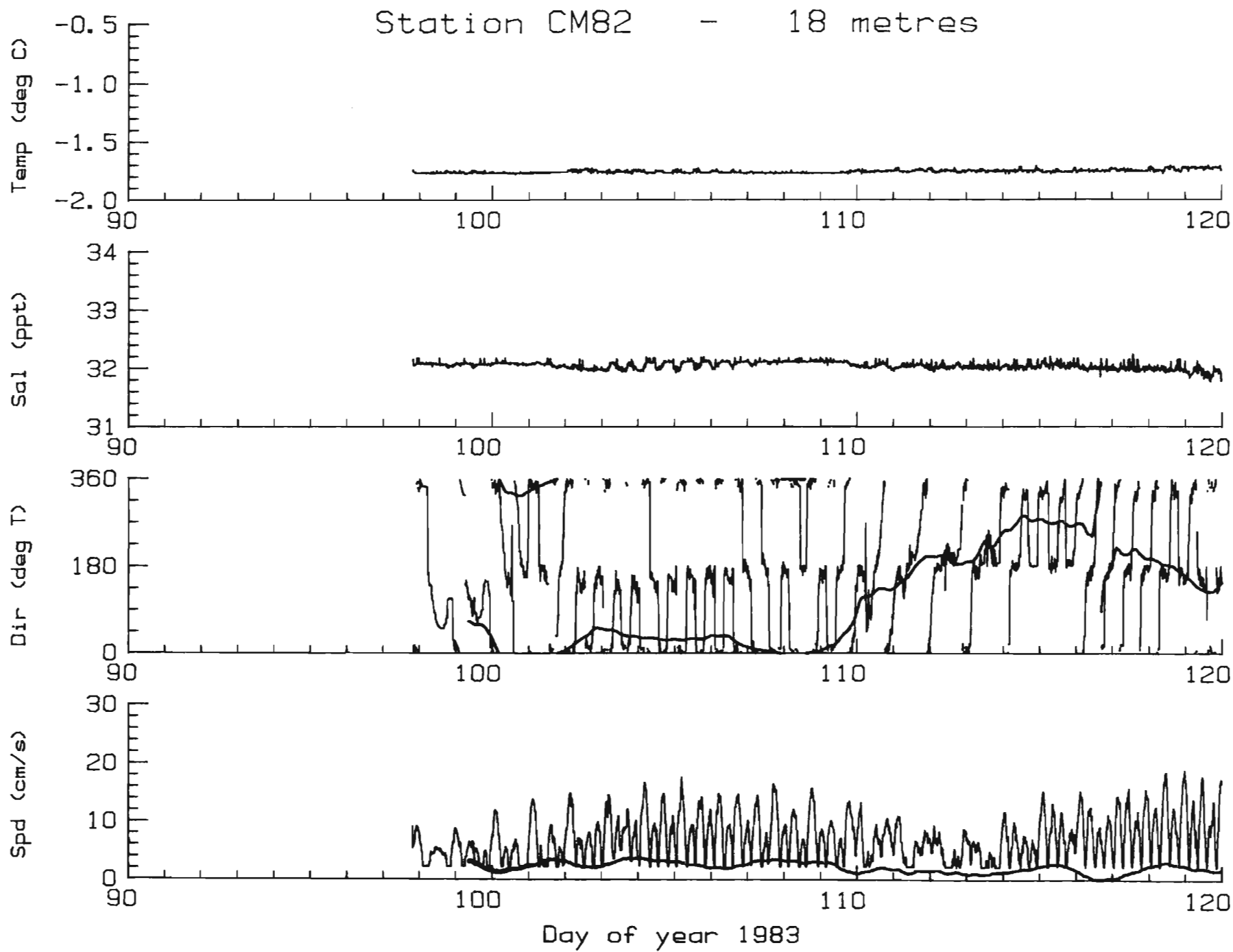
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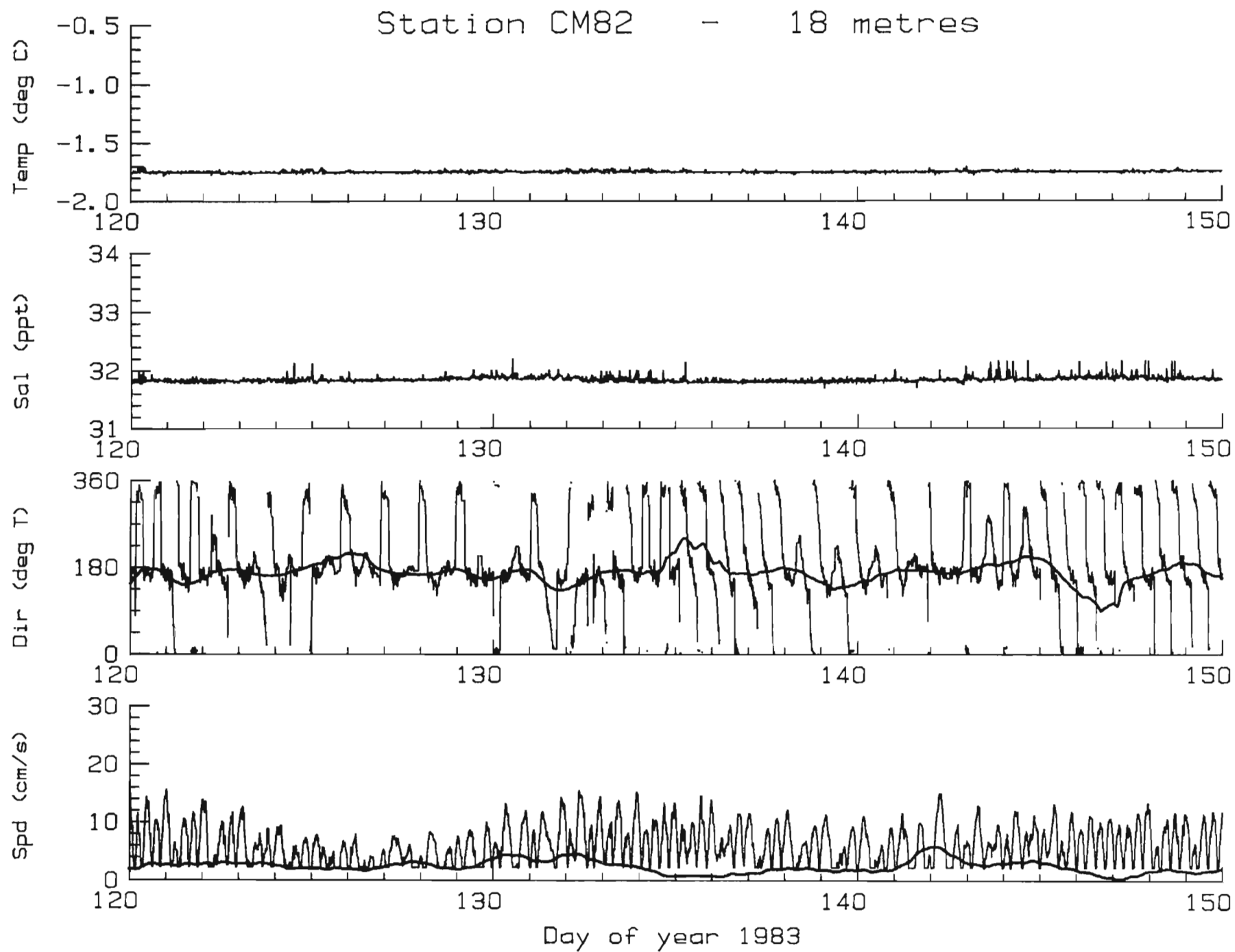


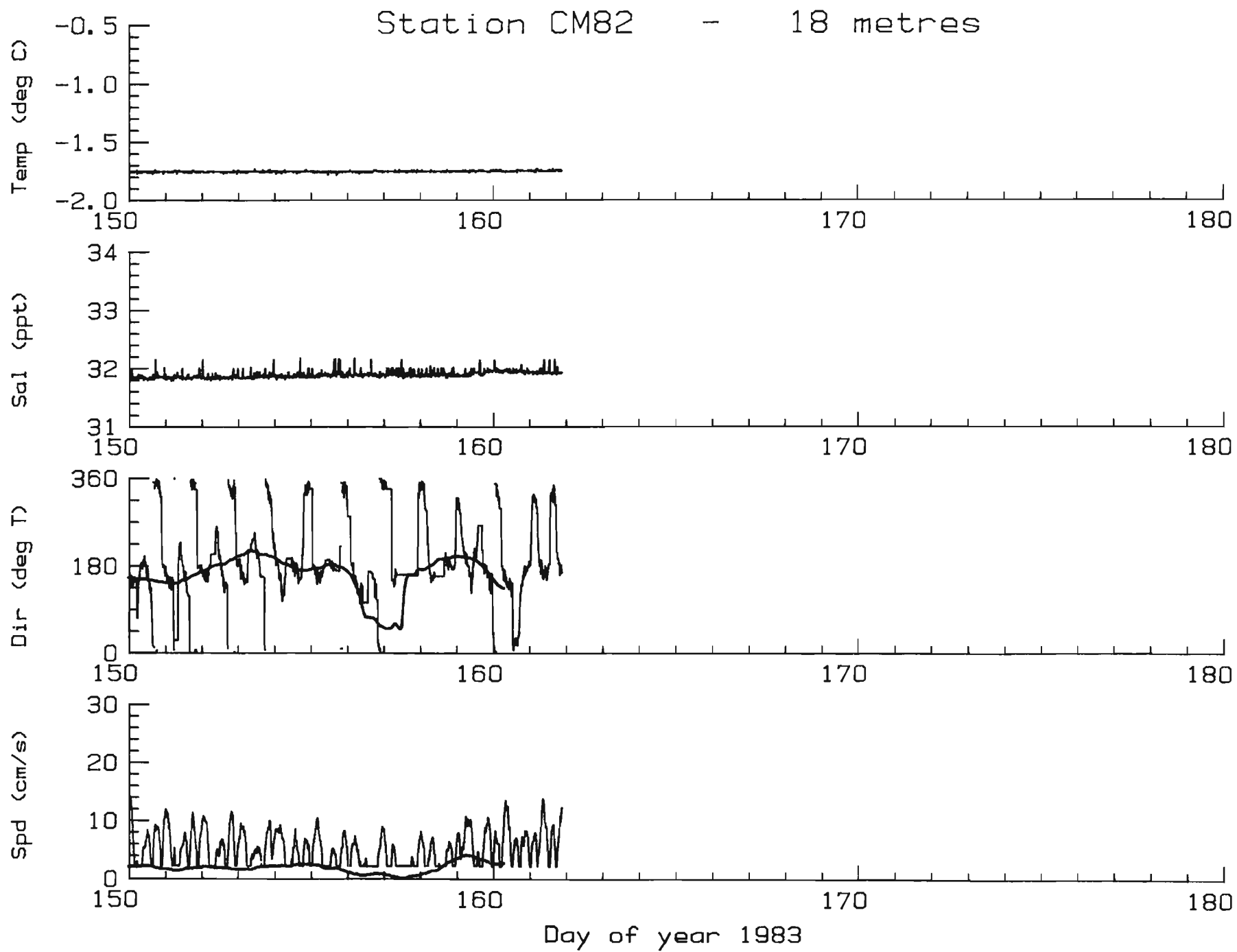


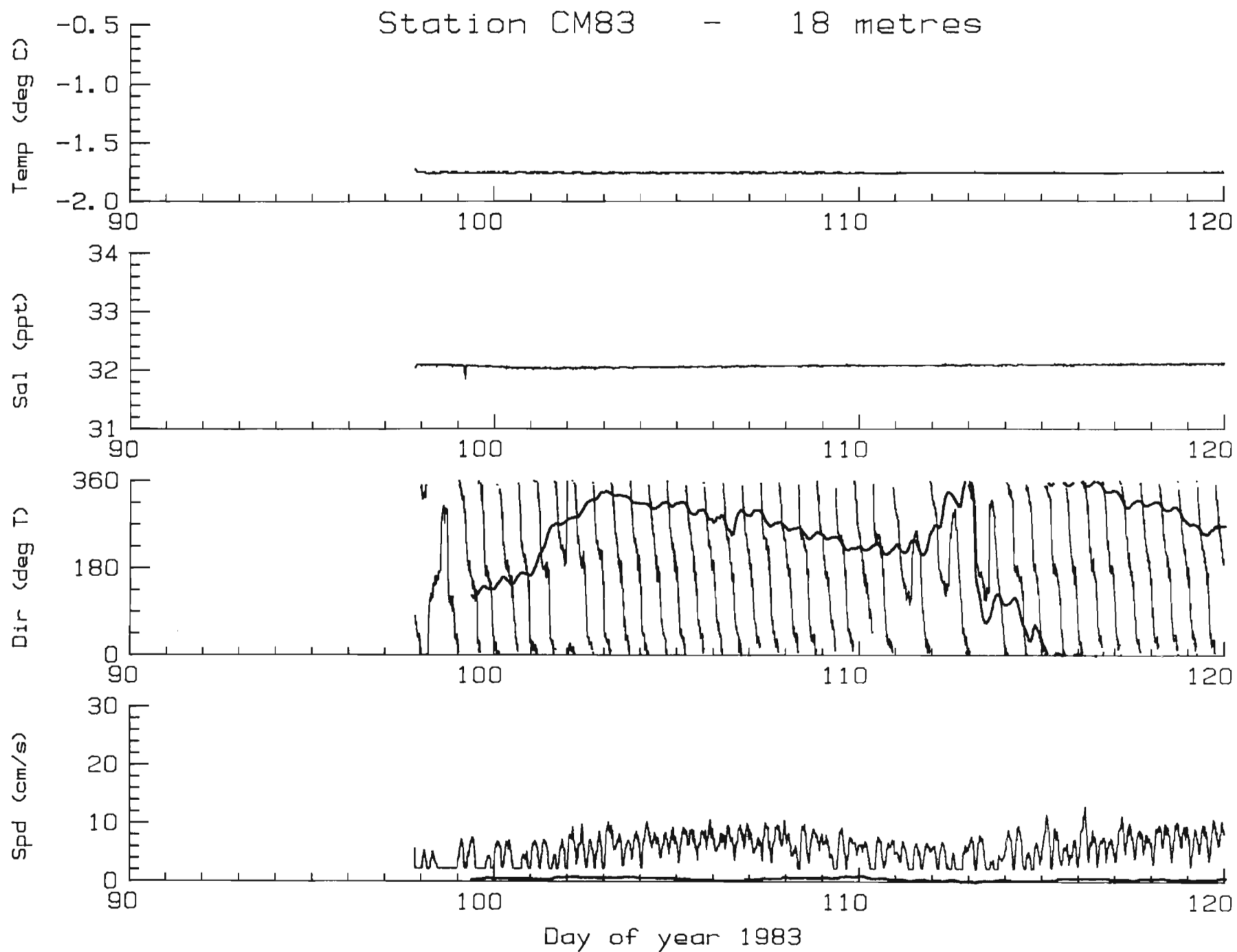




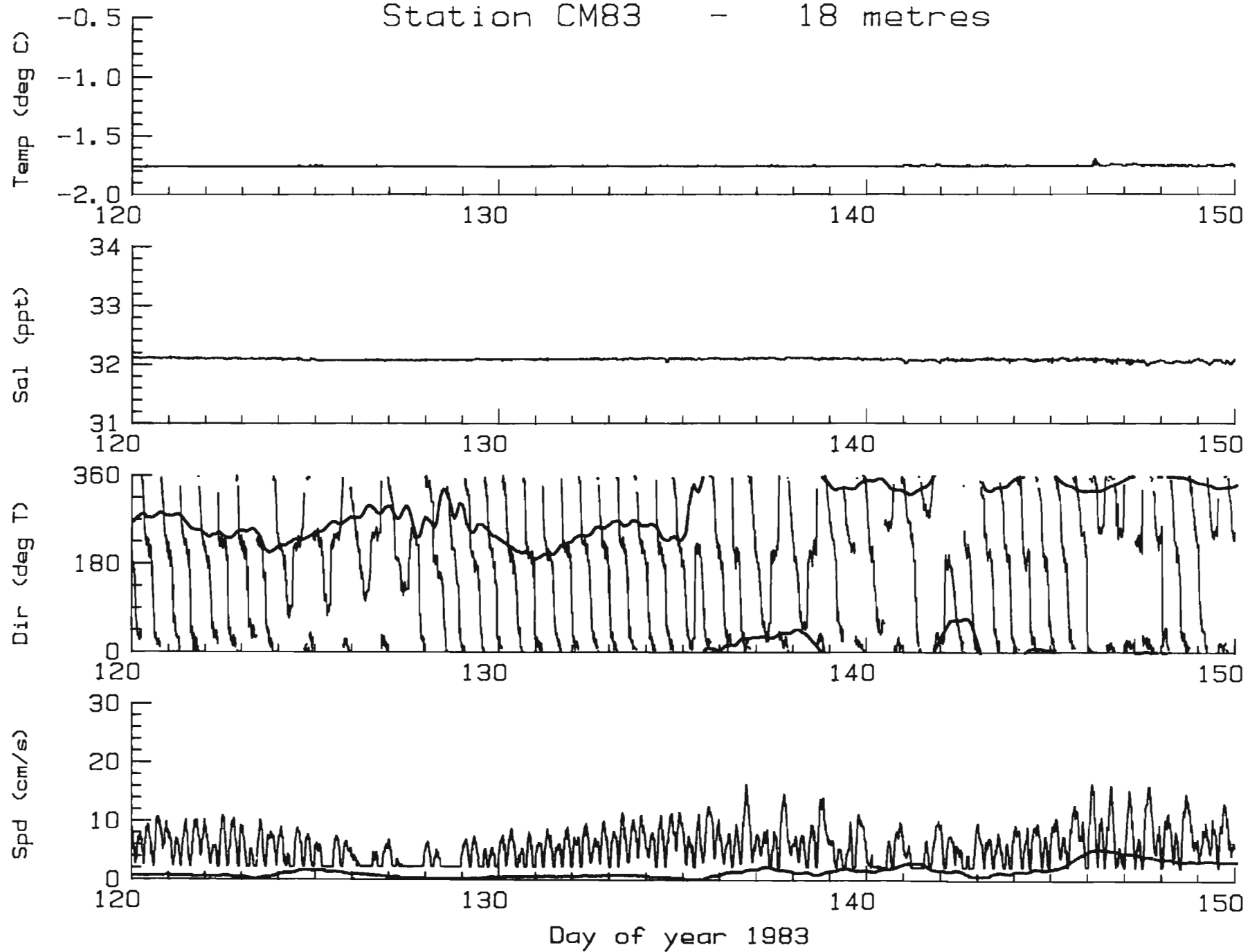


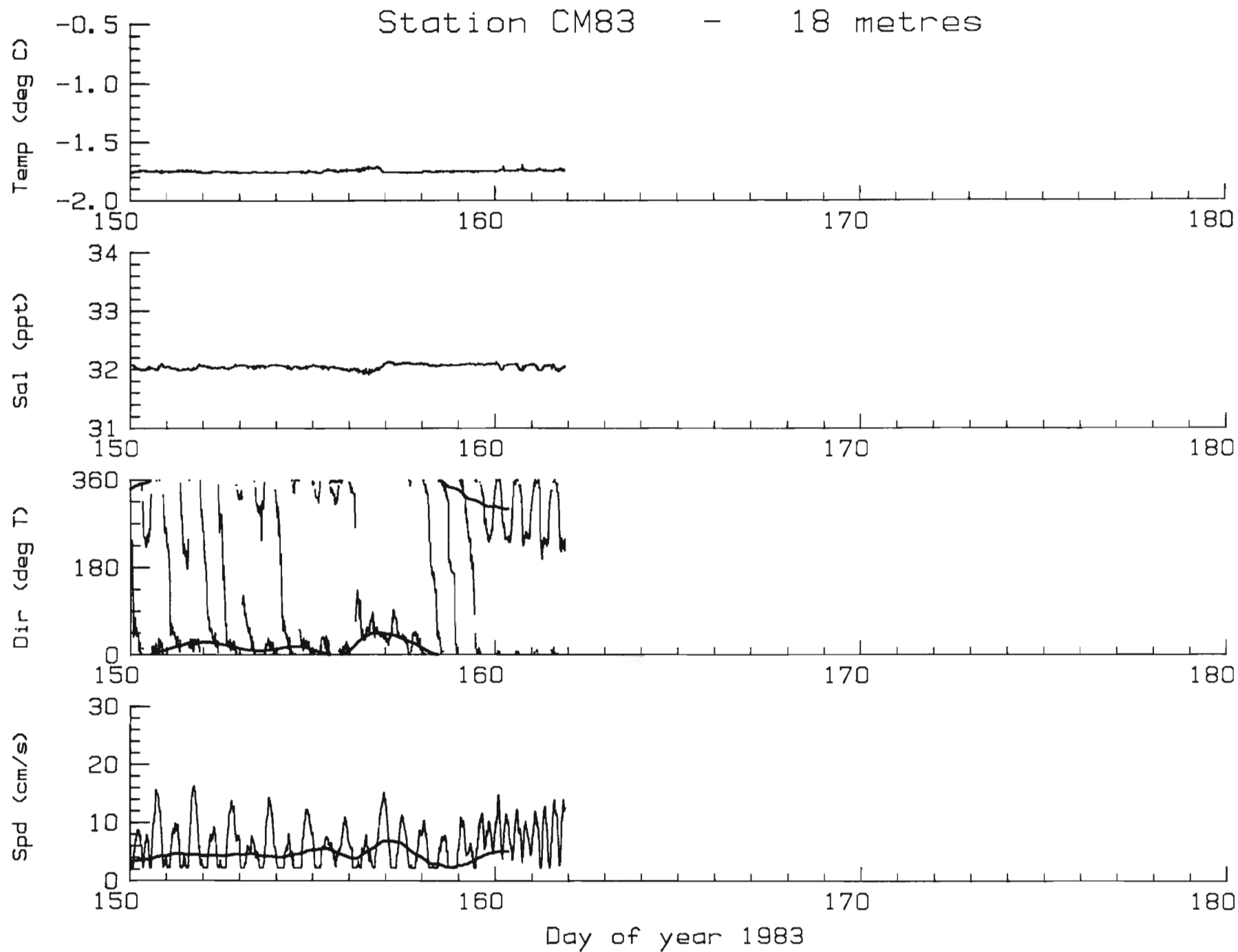


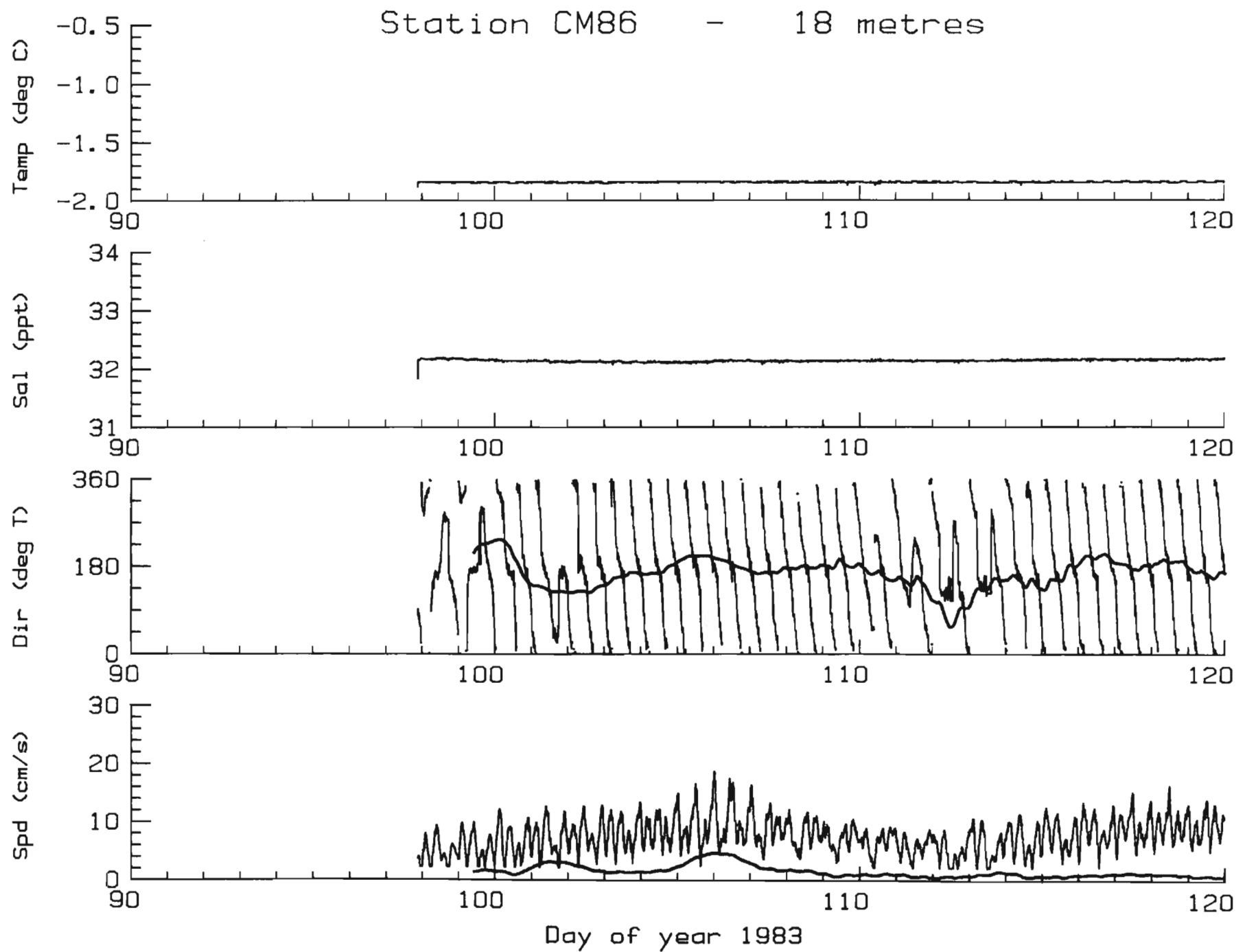


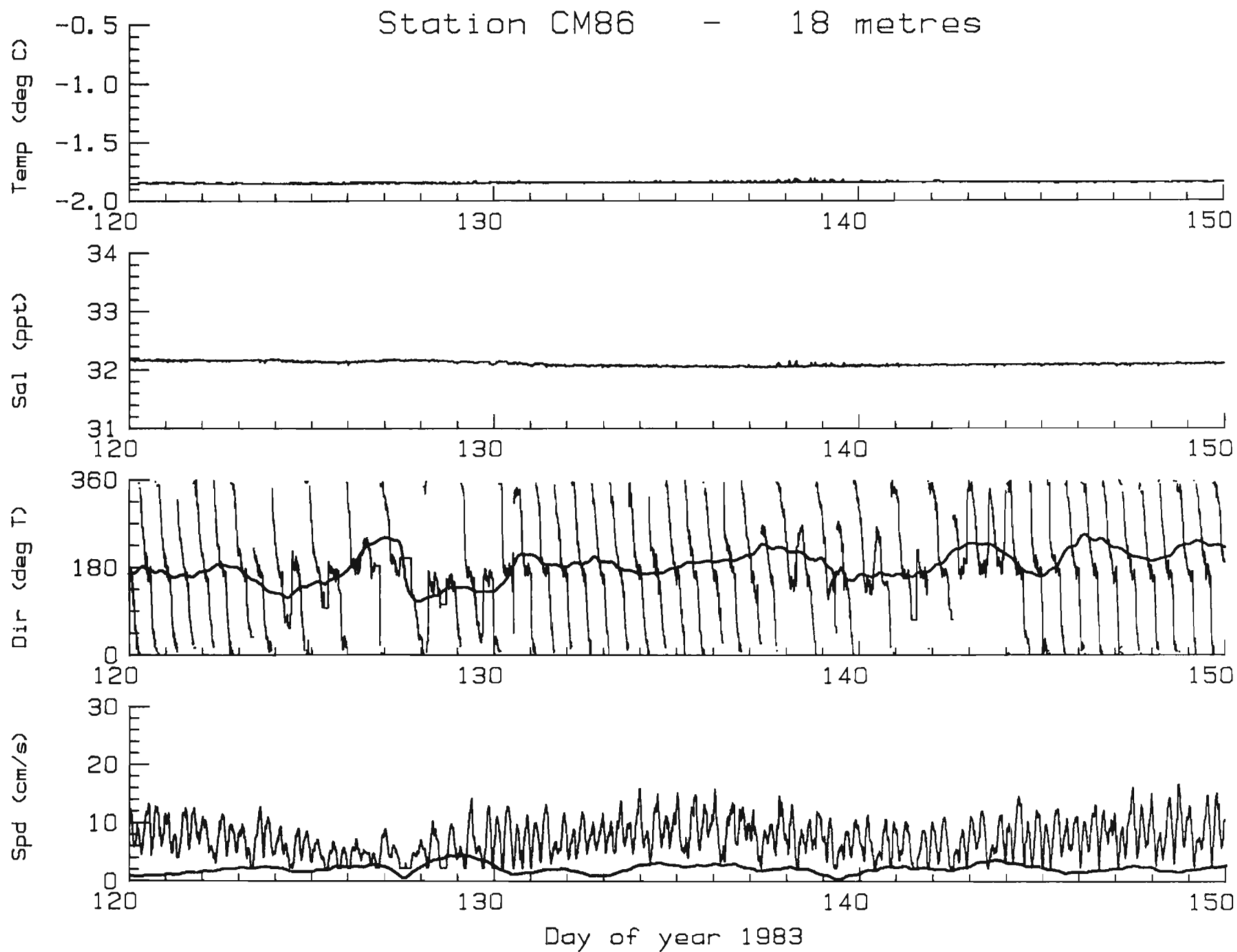


Station CM83 - 18 metres

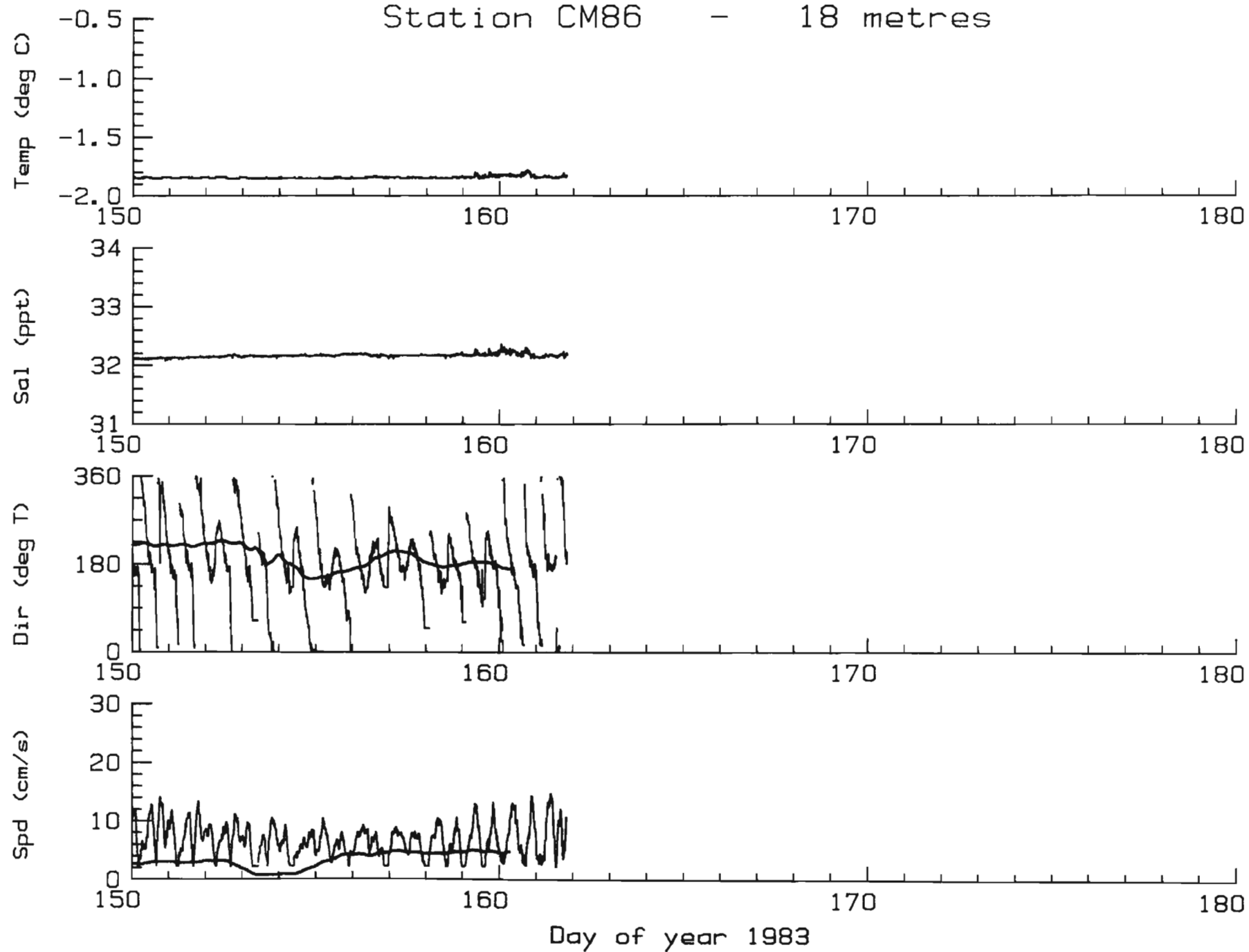




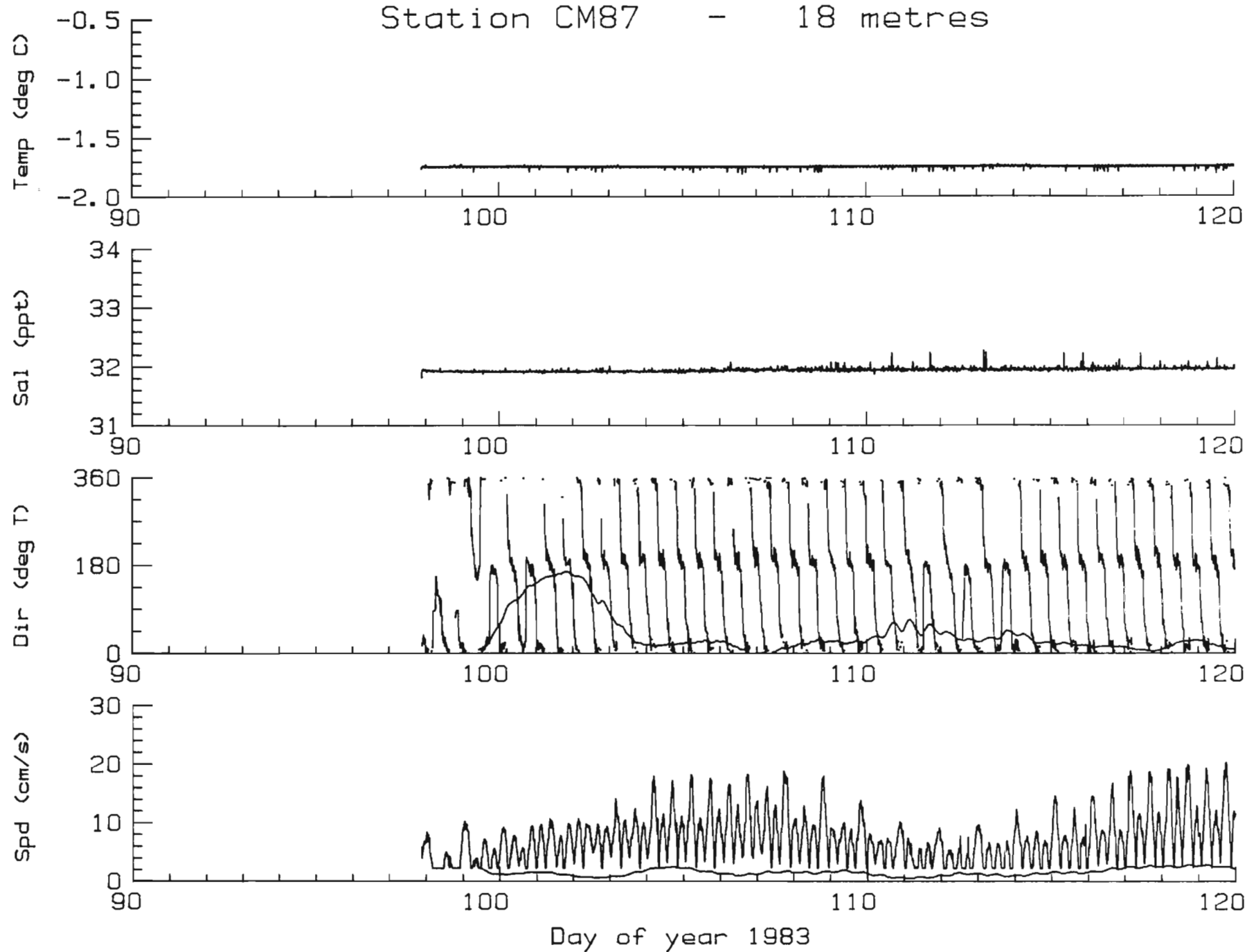


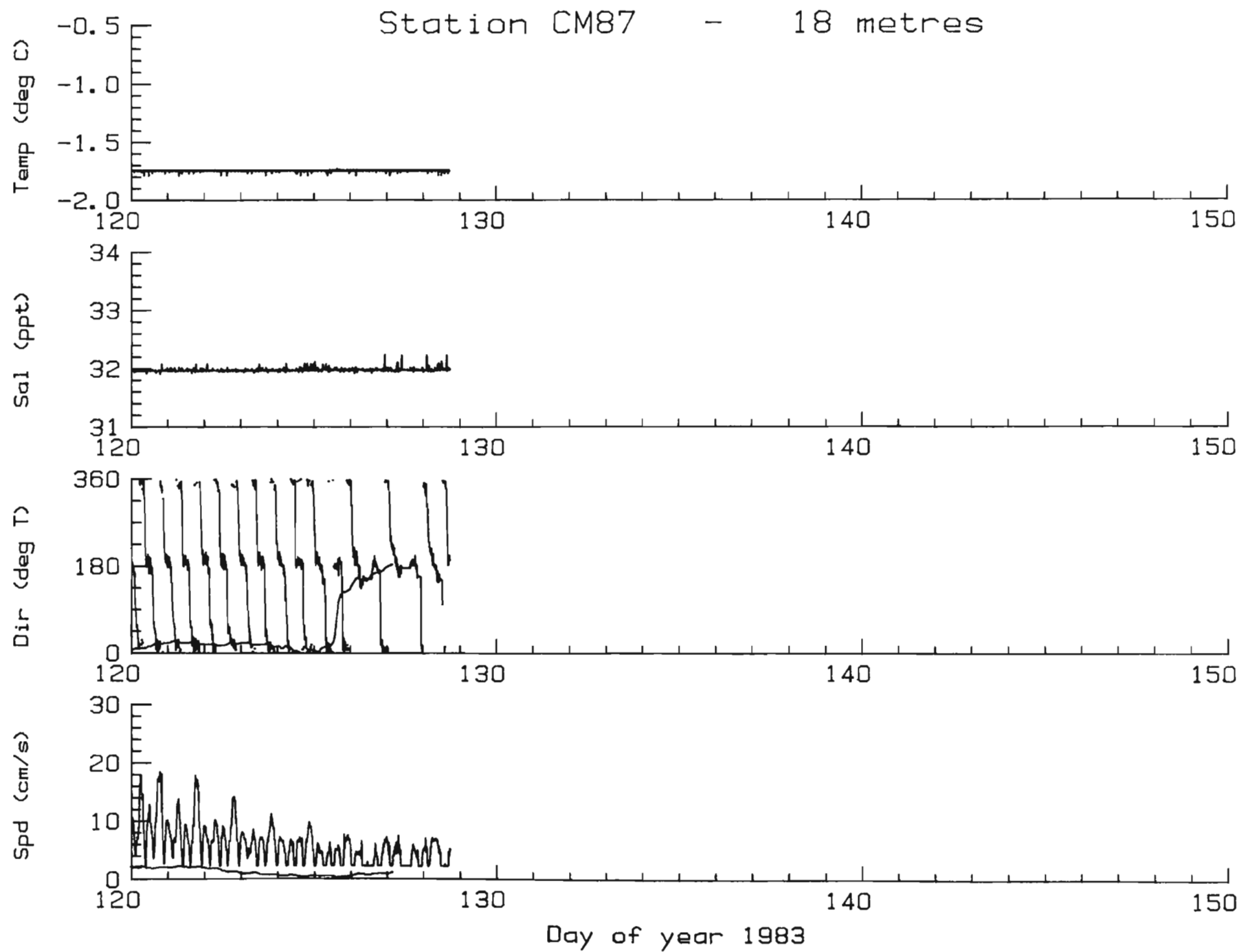


Station CM86 - 18 metres

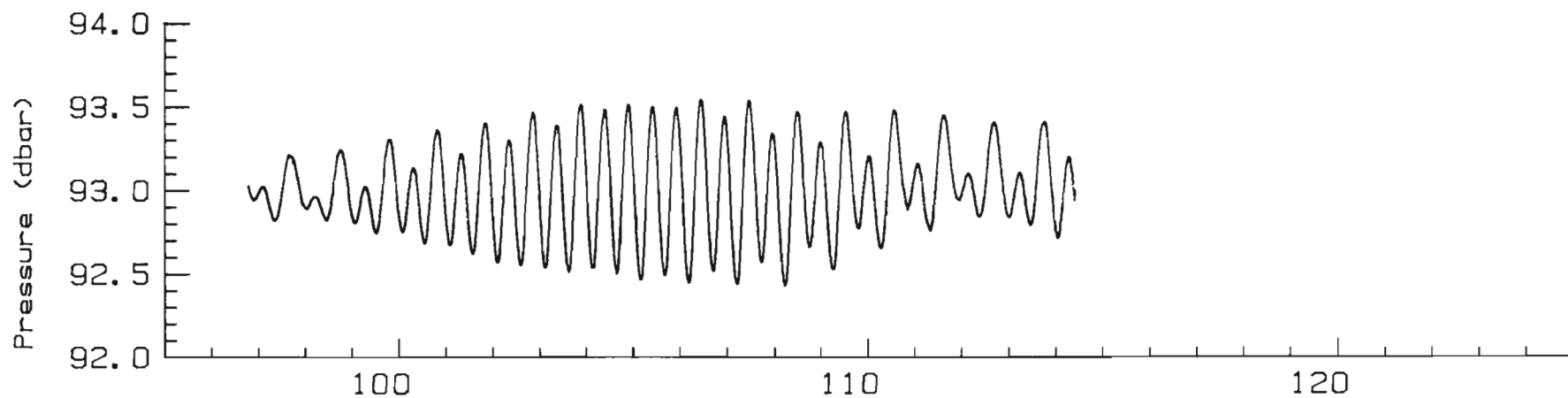


Station CM87 - 18 metres





Station CAPE COCKBURN



Station BYAM MARTIN CHANNEL

