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Some current and temperature observations in the Mediterranean outflow west of Gibraltar; a data report

by

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With 45 figures and 1 table

Beobachtungen der Strömungs- und Temperaturverhältnisse im Mittelmeerausstrom westlich Gibraltar; eine Daten-Übersicht

Zusammenfassung

Auf der „Nordost-Atlantik-Expedition" mit F. S. „Meteor" wurden im Frühjahr 1971 einen Monat lang auf 7 Positionen westlich von Gibraltar mit 29 Strommessern und 5 Thermistorketten die Temperatur- und Strömungsverhältnisse beobachtet. Die Geräte waren vorwiegend zur Registrierung der zeitlichen Veränderlichkeit des durch die Straße von Gibraltar in den Atlantik ausfließenden Mittelmeerwassers bestimmt. In der vorliegenden Arbeit werden die Zeitserien der Temperatur- und Stromvariationen, deren Amplitudenspektren und die aneinander gereihten Stromvektoren als Basis für die weitere Bearbeitung dargestellt. Charakteristische Periodenbereiche der zeitlichen Veränderlichkeit lassen sich aus dem vorhandenen Datenmaterial direkt ablesen.

Abstract

At seven sites west of Gibraltar current and temperature variations of the Mediterranean outflow were observed during one month in spring 1971. This paper presents the obtained records of 29 current meters and 5 thermistor cables in the form of time series, amplitude spectra, and progressive vector diagrams as a basis for further evaluation. Characteristic features of the currents like mean speeds, mean directions and the periodicity of the variation can be seen directly from the given plots.

Introduction

The main problem to be investigated during the "Northeast Atlantic Expedition" with F. S. "Meteor" was the effect of the Mediterranean water on the stratification and mixing of sea water and on the sedimentation at the continental slope west of Gibraltar. Various time series of temperatures and currents were obtained by means of seven subsurface moorings. They were placed in areas where the undercurrent has close contact to the sea floor, where the outflow starts its horizontal spreading, and in deep water with the Mediterranean core at intermediate levels. Details about the positions of the mooring sites and their relation to the outflow channels are described in the report of the coordinator of the expedition (Siedler 1972).

This paper presents the set of data from the moored instruments in graphical form as a basis for further evaluation.

Instrumentation

The mooring technique applied in this investigation has been developed at the Institut für Meereskunde, Kiel (Siedler et al. 1970, Engelmann 1972). The effect of oscillations of the moorings can probably be neglected here because the sensors were mostly placed in the nearbottom Mediterranean outflow. In general, the mooring inclination was mainly controlled by rather strong mean currents. All arrays were equipped with Aanderaa meters and thermistor cables (Aanderaa 1964, 1967). The clocks used were especially developed for these meters by the Institut für Satellitenelektronik (Bücklein 1971). The main advantage of the crystal clocks is their high reliability. On the average the clocks lost approximately 4 sec per day. The sampling rate of the instruments was once every 5 min. for the current meters and once

every 10 min. for the thermistor cables. The local magnetic deviation for the area of investigation was taken into account during the data processing. Unfortunately it was not possible to recalibrate the thermistors a short time before the cruise. The last calibration was done 14 months before the expedition. Apparently the drift exceeded the specifications over this period, and therefore the mean value at neighbouring levels sometimes differs considerably. E. g. record 20 102 T 1 at 704 m depth on the average is 0.13 °C lower than record 20 101 T at 697 m. It can, however, be assumed that the drift was small for the period of this experiment, and the fluctuations presented here are not contaminated by the drift.

Of 36 instruments moored two gave no data at all. In addition, record 19 102 only lasted for 2/3 of the mooring period because of battery problems. A leakage at the lower end of the thermistor cable 19 104 caused a failure of the lower sensors.

Presentation of the data

The positions of the moorings are given in fig. 1, the duration of the individual records is indicated in fig. 2. The obtained data are given in the sequence of their IfM reference numbers (19–25) following the Mediterranean outflow from east to west. The mean currents and the mean temperatures were subtracted before plotting the east (U) and north (V) components of the currents and the temperature (T). Data points selected at ten minute intervals were used for the graphical presentation. The vertical reference lines indicate weeks. The amplitude spectra for the period range 2–120 h were computed from the unfiltered time series. Because of the great similarity of temperature spectra for neighbouring depth levels, only selected spectra are given for the thermistor cables. The semi-diurnal M2 period and higher harmonics and the local inertial period (21 h) are given as reference lines. In order to present the predominant current directions, a set of progressive vector diagrams was plotted.

Table 1 Summary of presented data, indicating numbers of figures: U, V — East, north components of current; T — Temperature.

Tabelle 1 Zusammenfassung der dargestellten Daten mit Angabe der Abbildungsnummern: U, V — Ost-, Nordkomponente des Stromes; T — Temperatur.

IfM Mooring No.	Figure No. Time Series		Amplitude Spectra		Progressive Vector Diagrams
	U, V	T	U, V	T	
19	3	4, 5, 6	9	7, 8	10
20	12	11, 13	14	15	16
21	18	17	19	20	21
22	23	22	24	25	26
23	28	27	29	30	31
24	32, 35	33, 36	34, 39	37, 38	40
25	41	42, 43	44	-	45

Acknowledgement

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References

AANDERAA, J. R. (1964): A recording and telemetering instrument. – Tech. Rep. NATO Sub. Comm. on Oc. Res., **16**: 53 pp.
(1967): Operating manual for recording current meter. – Serial no. 42–66, Nesttun, 30 pp.

BÖCKLEIN, R. (1971): Eine Kleinquarzuhr zur Steuerung von Meßsonden für die Meeresforschung. – DFVLR-Nachrichten, **5**: 196–198.

ENGELMANN, H. (1972): Untersuchungen an Komponenten für Tiefwasserverankerungssysteme. – Kieler Meeresforsch., **28** (2): 119–129.

SIEDLER, G. (1972): Nordost-Atlantik-Expedition 1971, Koordinatorbericht. Meteor-Forsch.-Ergebn. A, **10**, 79–95.

SIEDLER, G. & G. GRASSHOFF (1970): Tiefwasser-Verankerungssysteme des Instituts für Meereskunde Kiel. – Kieler Meeresforsch., **26** (1): 21–42.

Received: 21. 9. 1973

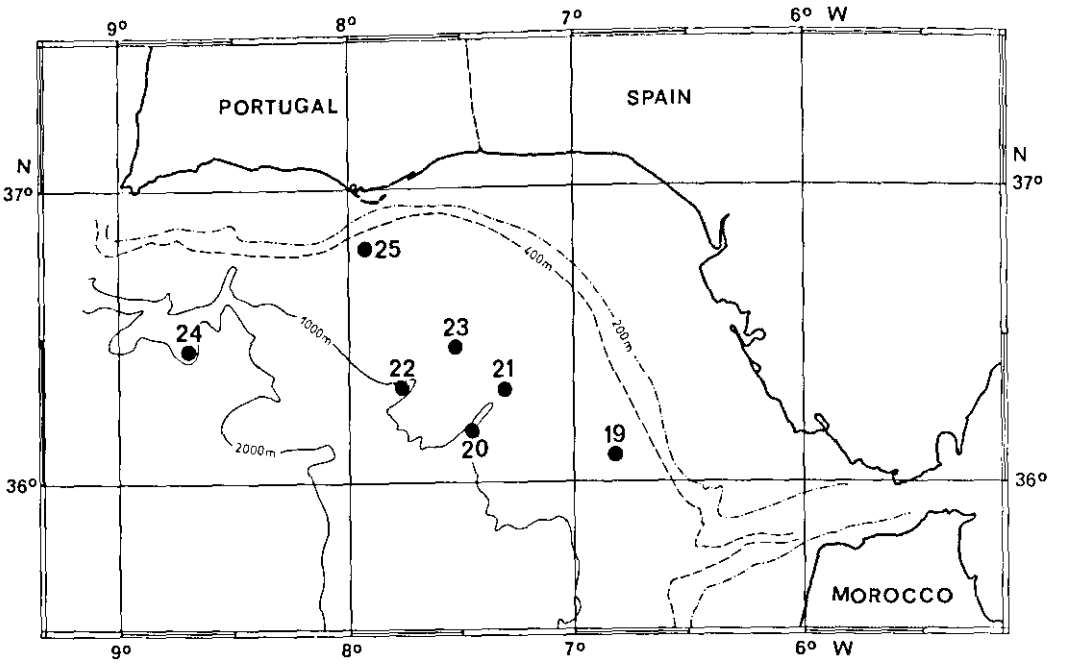


Fig. 1. Map of area investigated by F. S. Meteor in spring 1971. Mooring sites and respective IfM reference numbers are indicated.

Abb. 1. Karte des Untersuchungsgebietes von F. S. Meteor im Frühjahr 1971. Orte und zugehörige IfM-Verankerungsnummern sind gekennzeichnet.

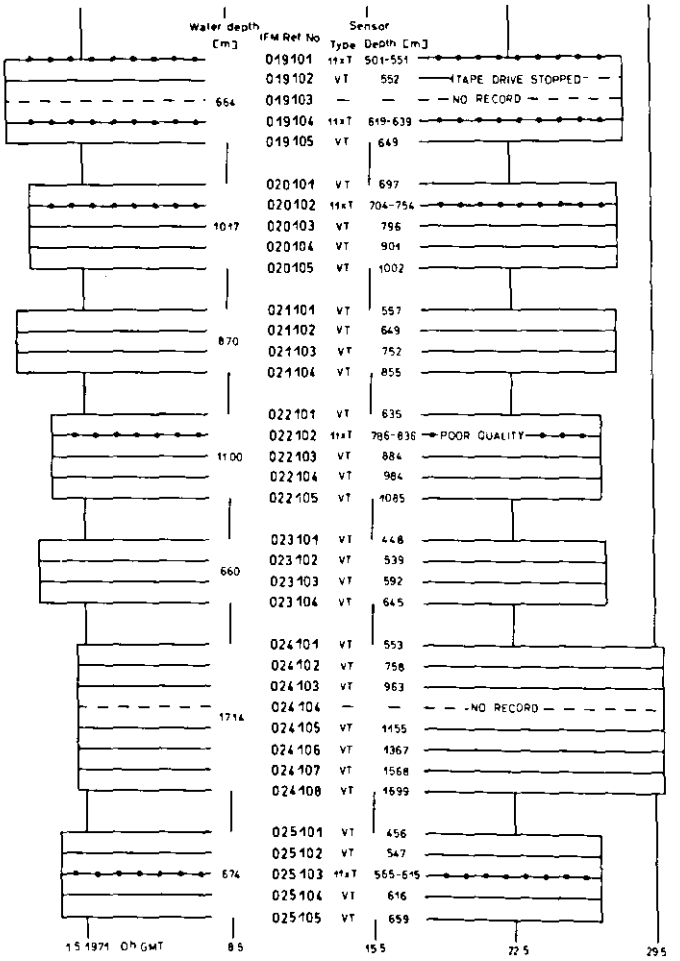


Fig. 2. The duration of the time series. The following abbreviations are used: V — velocity; T — temperature; 11 × T — thermistor cable; ———— — current meters; -.-.-.-.- — thermistor cables; - - - - - - - — no data obtained.

Abb. 2. Dauer der Zeitserien. Folgende Abkürzungen wurden verwandt: V — Geschwindigkeitsvektor; T — Temperatur; 11 × T — Thermistorkette; ———— — Strommesser; -.-.-.-.- — Thermistorkabel; - - - - - - - — keine Daten.

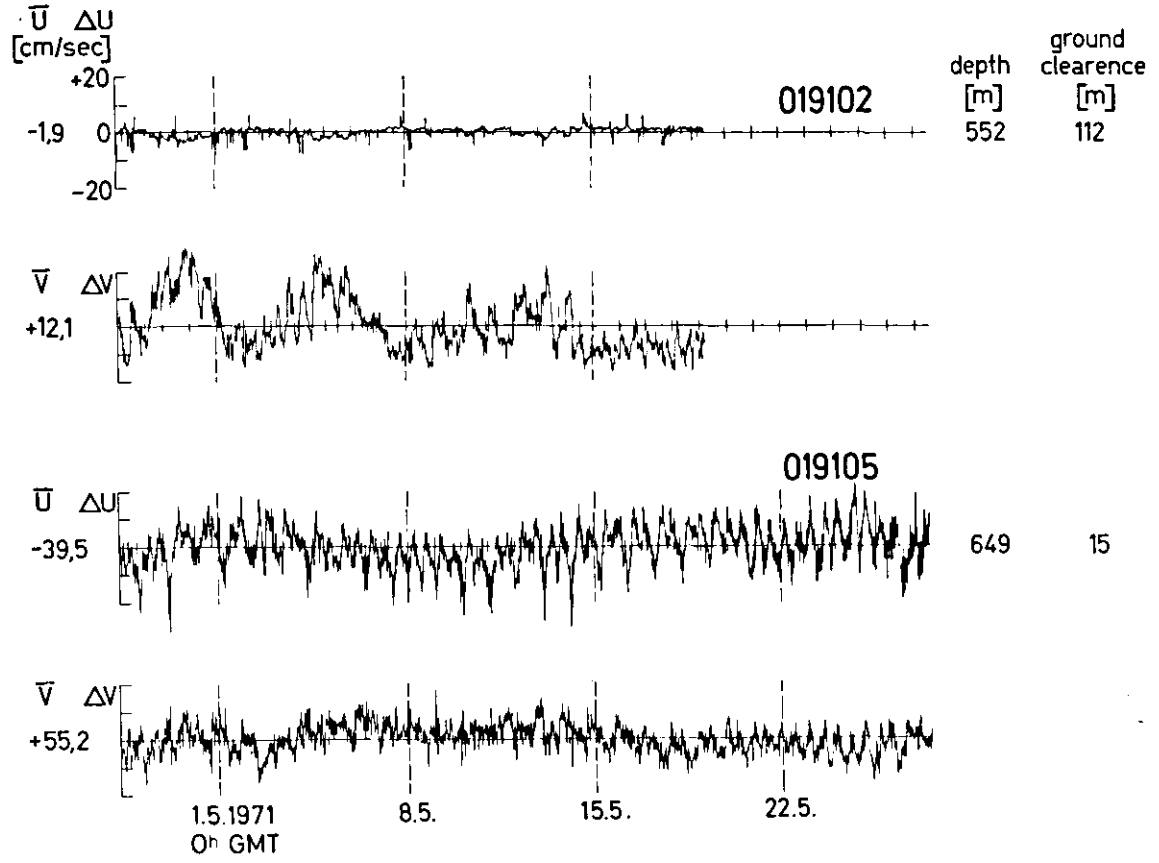


Fig. 3

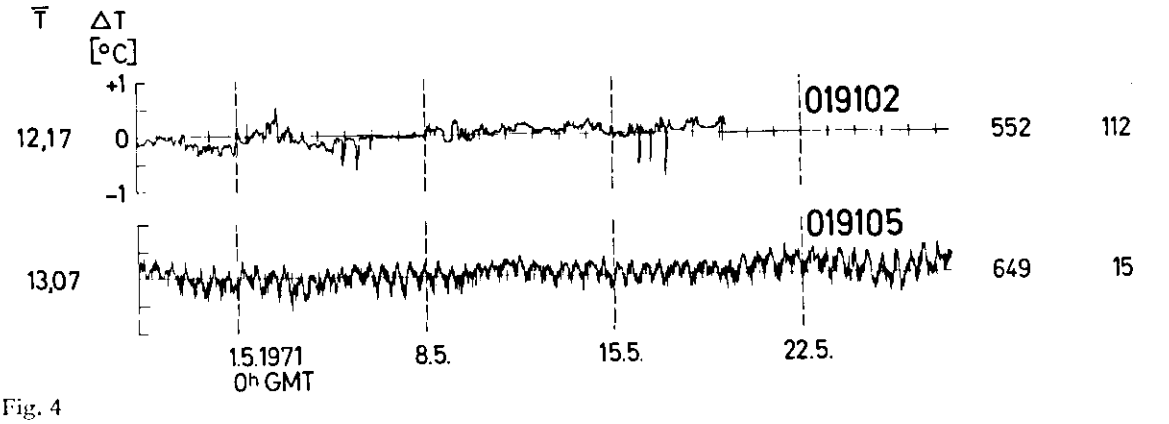


Fig. 4

Explanations for figs. 3–45. The following abbreviations are used in the figures:

$\bar{U}$, $\bar{V}$ – Mean east and north components (resp.) of the currents;
– Mittlere Ost- bzw. Nordkomponente des Stroms;

ΔU, ΔV – Deviations from $\bar{U}$ and $\bar{V}$ (resp.);
– Abweichungen von $\bar{U}$ bzw. $\bar{V}$;

$\bar{T}$ – mean temperature;
– Mittlere Temperatur;

Erläuterungen zu den Abbildungen 3–45. Folgende Abkürzungen wurden in den Abbildungen verwandt:

ΔT – Deviation from $\bar{T}$;
Abweichungen von $\bar{T}$;

A_u, A_v – Amplitude spectra of the east and north components (resp.) of the currents;
– Amplitudenspektrum der Ost- bzw. Nordkomponenten U, V des Stromes;

A_T – Amplitude spectrum of the temperature.
– Amplitudenspektrum der Temperatur T.

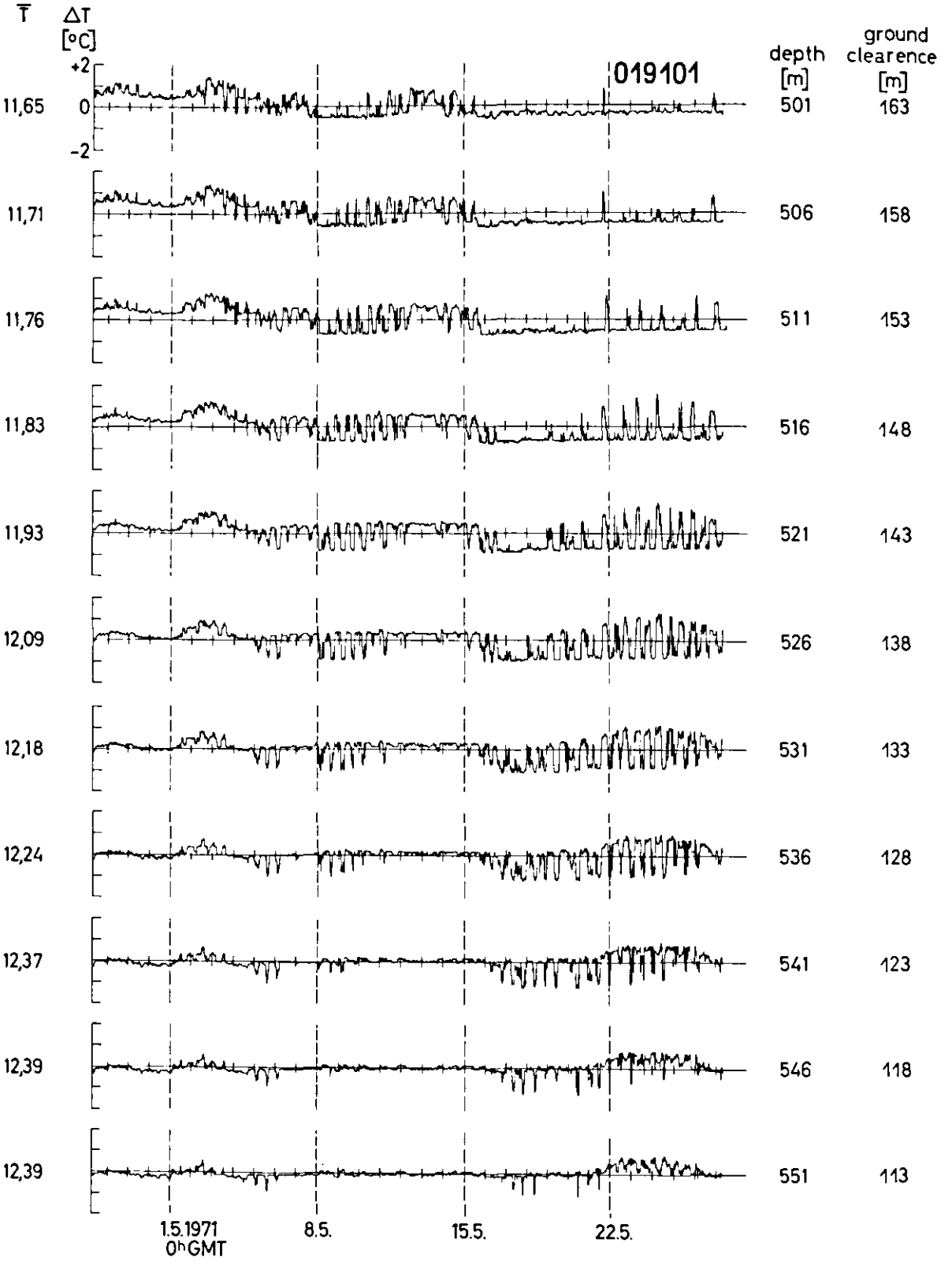

T̄
ΔT [°C]
+2
0
-2
019101
depth [m]
ground clearence [m]
11,65 501 163
11,71 506 158
11,76 511 153
11,83 516 148
11,93 521 143
12,09 526 138
12,18 531 133
12,24 536 128
12,37 541 123
12,39 546 118
12,39 551 113
1.5.1971 0hGMT
8.5.
15.5.
22.5.

Fig. 5

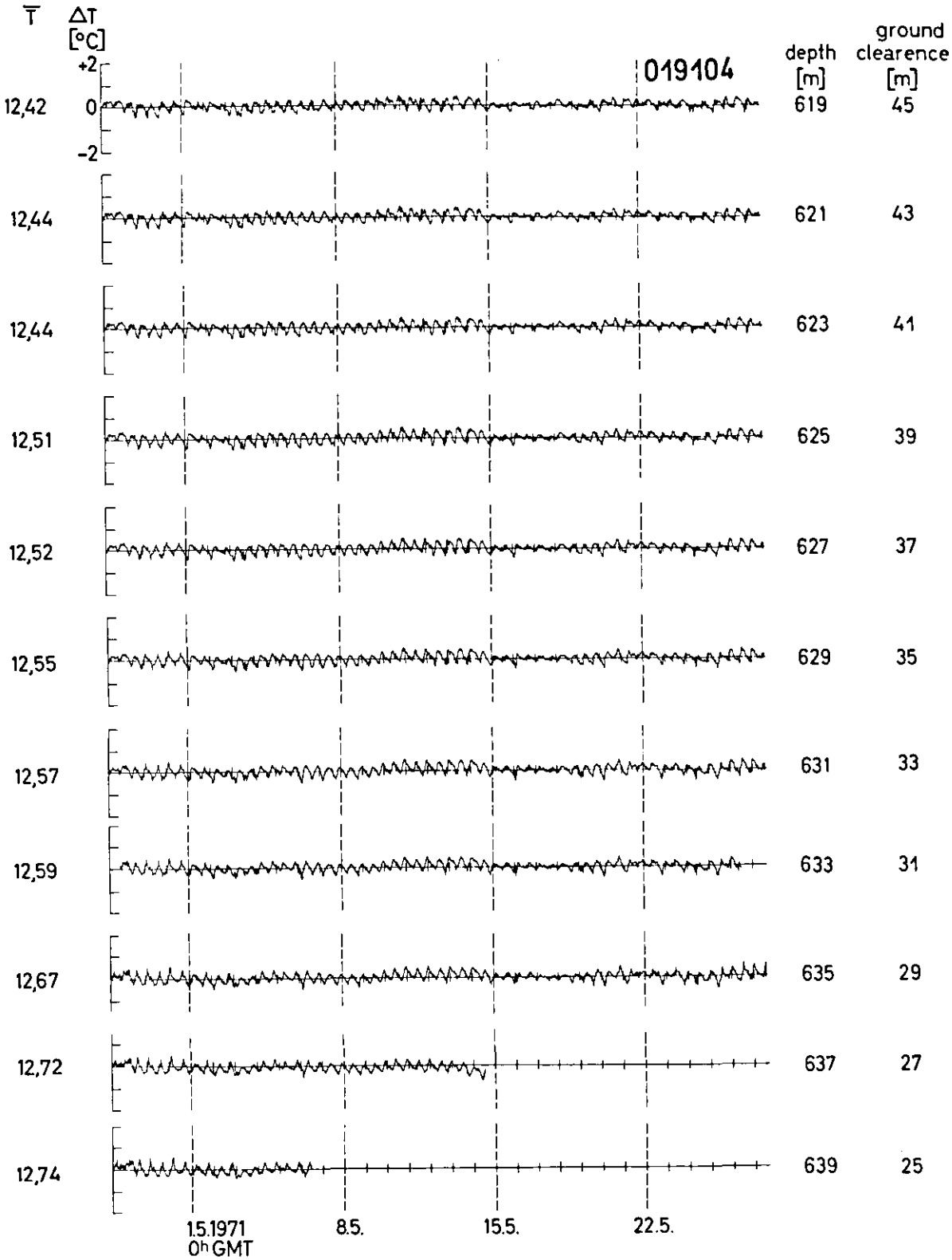

T
ΔT [°C]
+2
0
-2
019104
depth [m]
ground clearence [m]
12,42
619
45
12,44
621
43
12,44
623
41
12,51
625
39
12,52
627
37
12,55
629
35
12,57
631
33
12,59
633
31
12,67
635
29
12,72
637
27
12,74
639
25
1.5.1971 0h GMT
8.5.
15.5.
22.5.

Fig. 6

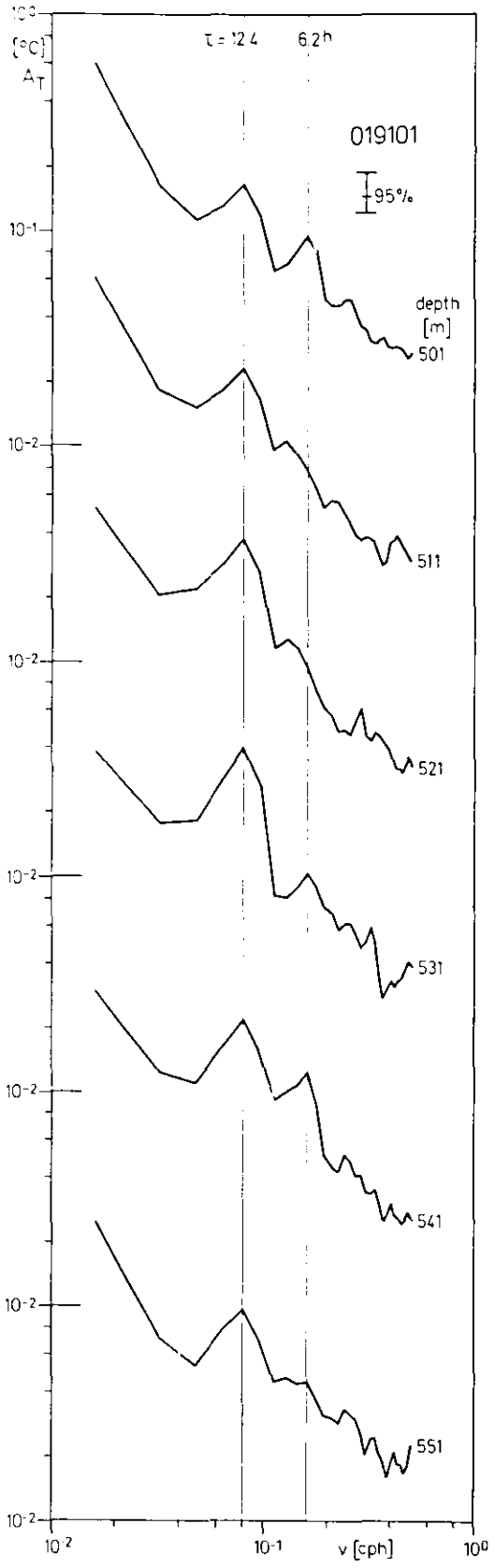

[°C]
A_T
τ = 12.4 6.2h
019101
95%
depth
[m]
501
511
521
531
541
551
10^{-1}
10^{-2}
10^{-2}
10^{-2}
10^{-2}
10^{-2}
10^{-2}
10^{-2}
10^{-1}
10^{0}
ν [cph]

Fig. 7

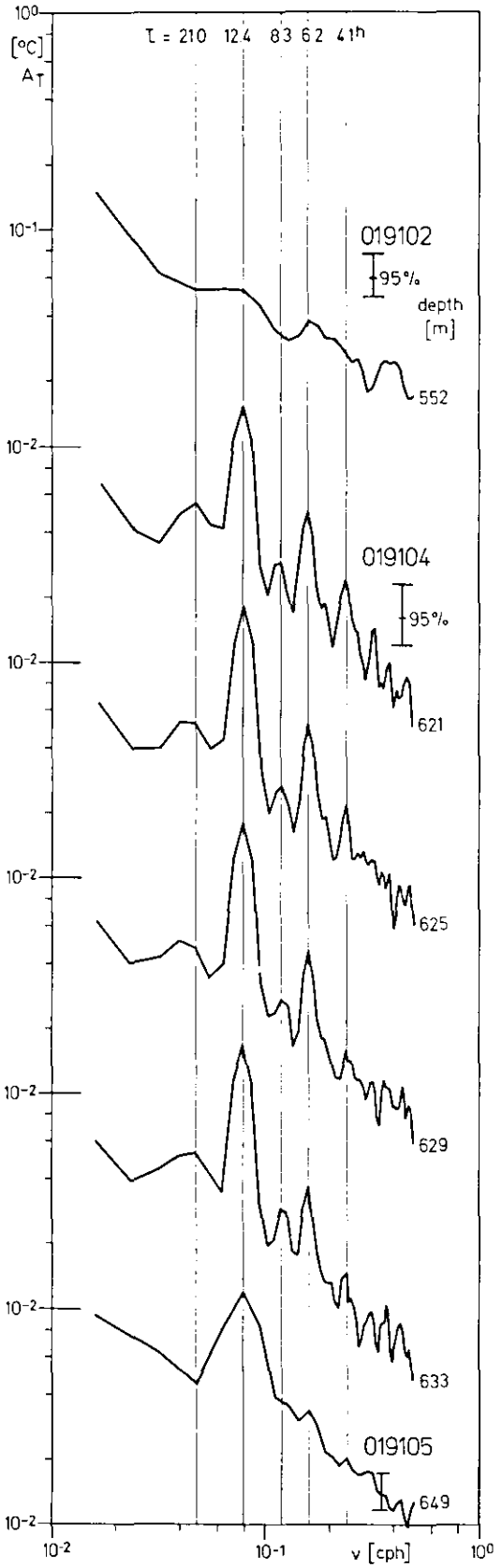

[°C]
A_T
τ = 21.0 12.4 8.3 6.2 4.1h
019102
95%
depth
[m]
552
019104
95%
621
625
629
633
019105
649
10^{-1}
10^{-2}
10^{-2}
10^{-2}
10^{-2}
10^{-2}
10^{-2}
10^{-2}
10^{-1}
10^{0}
ν [cph]

Fig. 8

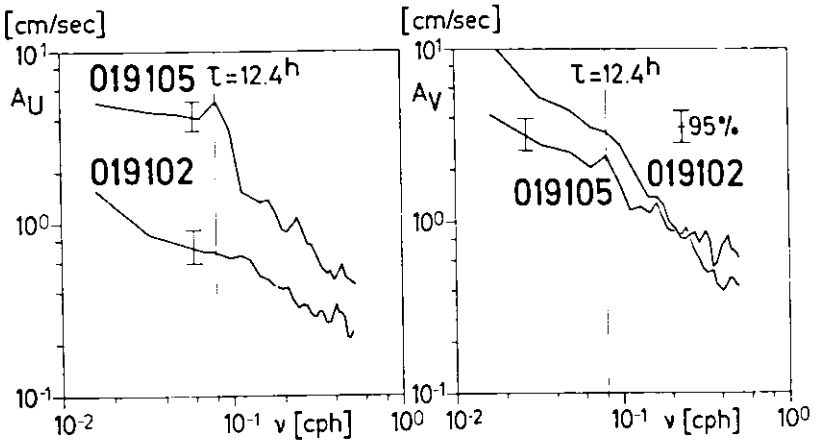


Fig. 9

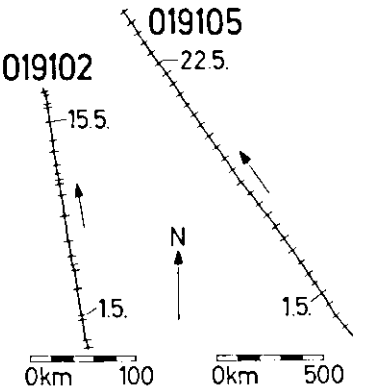


Fig. 10

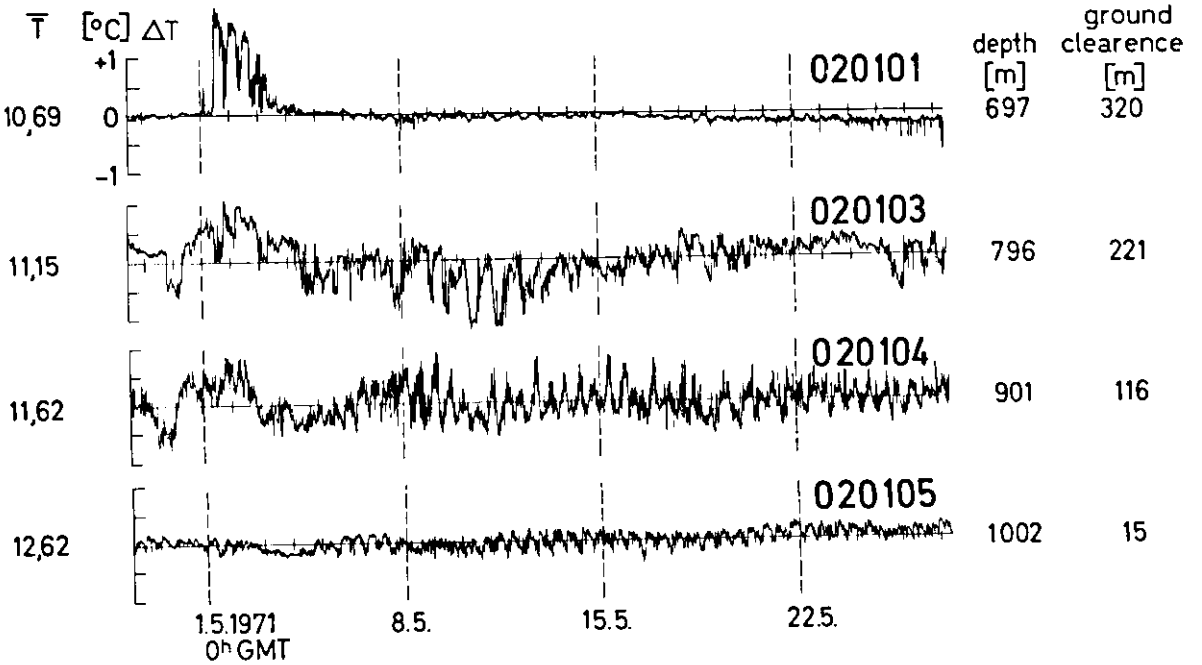


Fig. 11

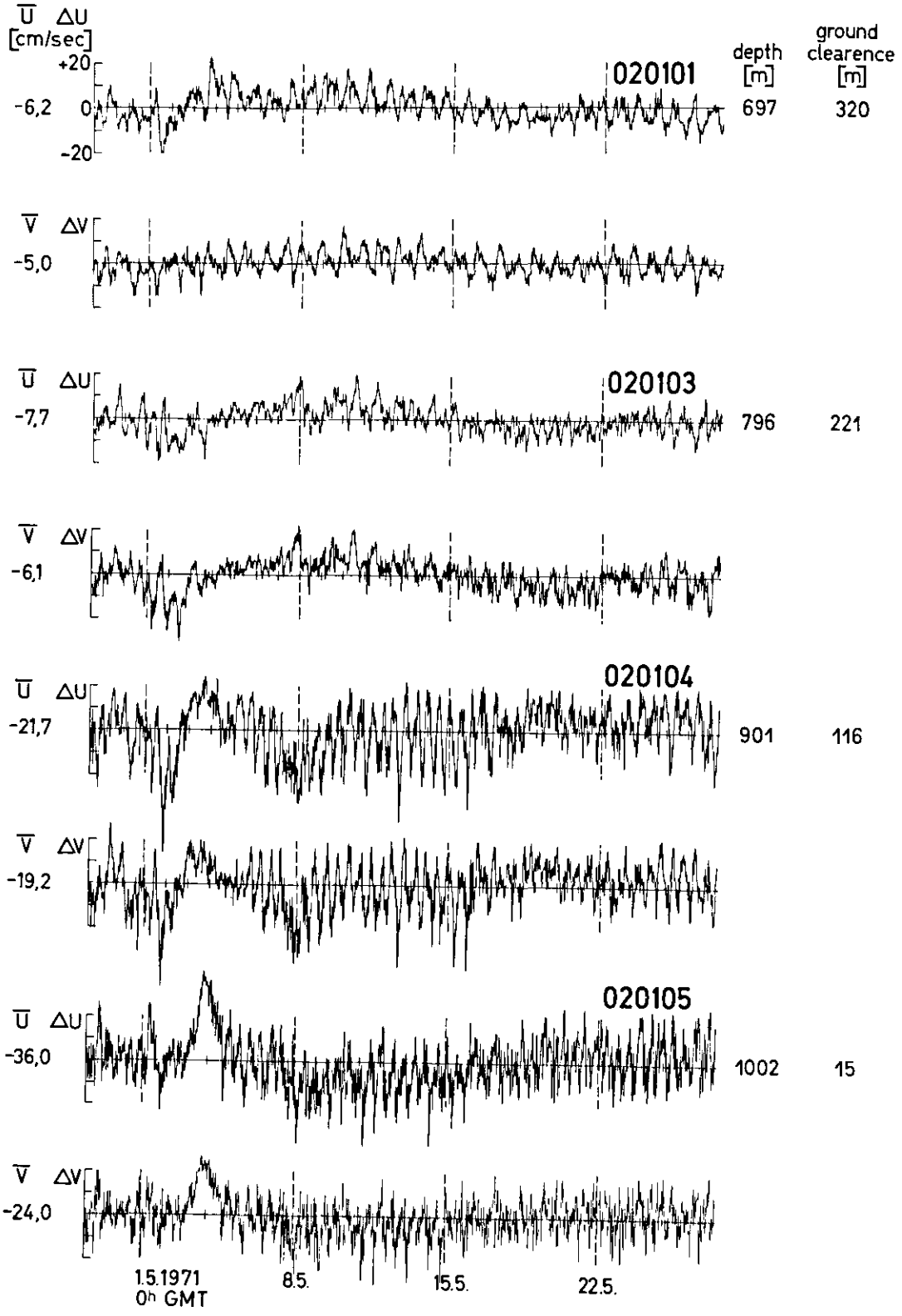

U ΔU
[cm/sec]
+20
-6,2
0
-20
020101
depth [m]
ground clearence [m]
697
320
V ΔV
-5,0
U ΔU
-7,7
020103
796
221
V ΔV
-6,1
020104
U ΔU
-21,7
901
116
V ΔV
-19,2
020105
U ΔU
-36,0
1002
15
V ΔV
-24,0
1.5.1971
0h GMT
8.5.
15.5.
22.5.

Fig. 12

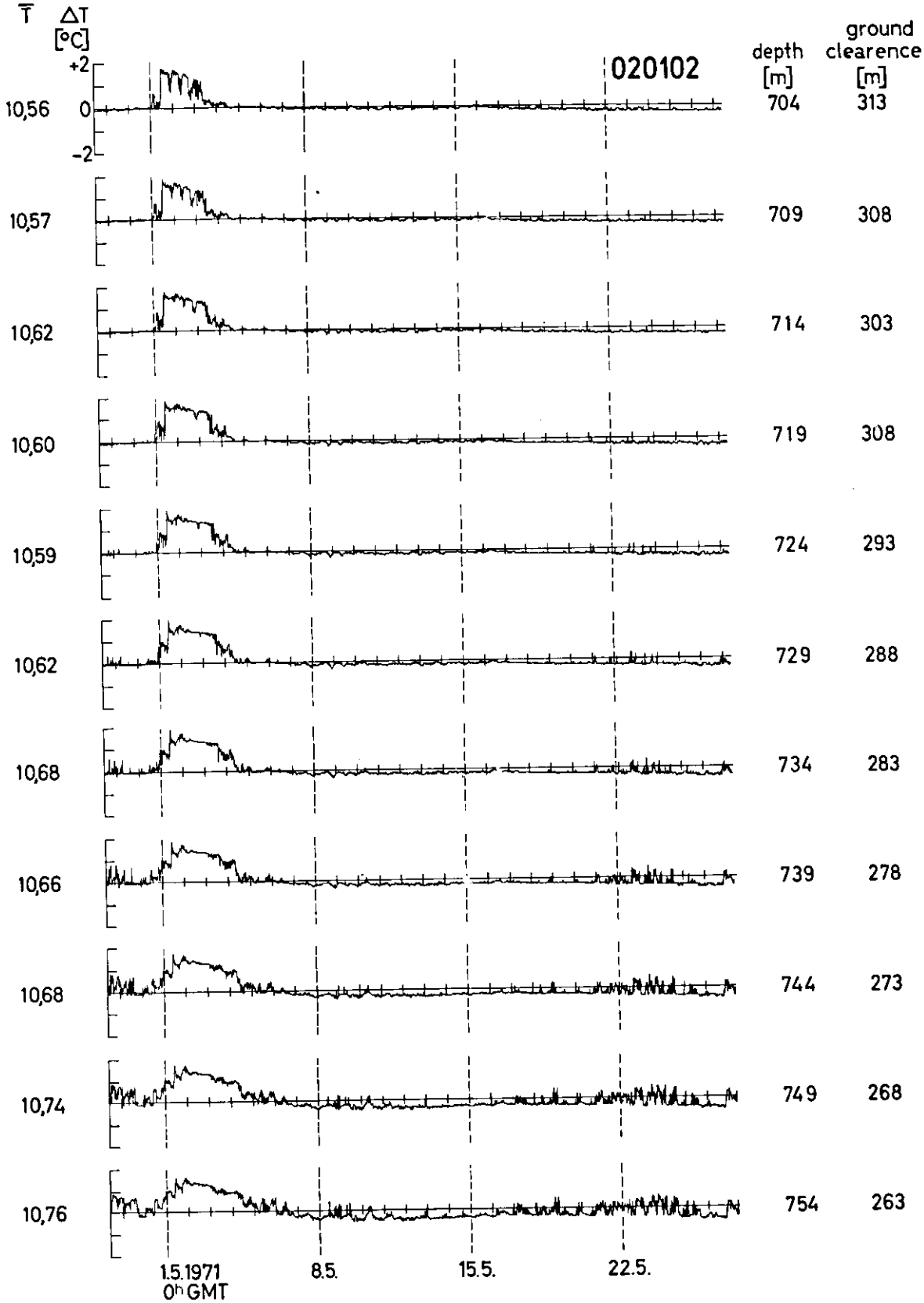

T̄
ΔT [°C]
+2
0
-2
020102
depth [m]
ground clearence [m]
10,56
704
313
10,57
709
308
10,62
714
303
10,60
719
308
10,59
724
293
10,62
729
288
10,68
734
283
10,66
739
278
10,68
744
273
10,74
749
268
10,76
754
263
1.5.1971 0h GMT
8.5.
15.5.
22.5.

Fig. 13

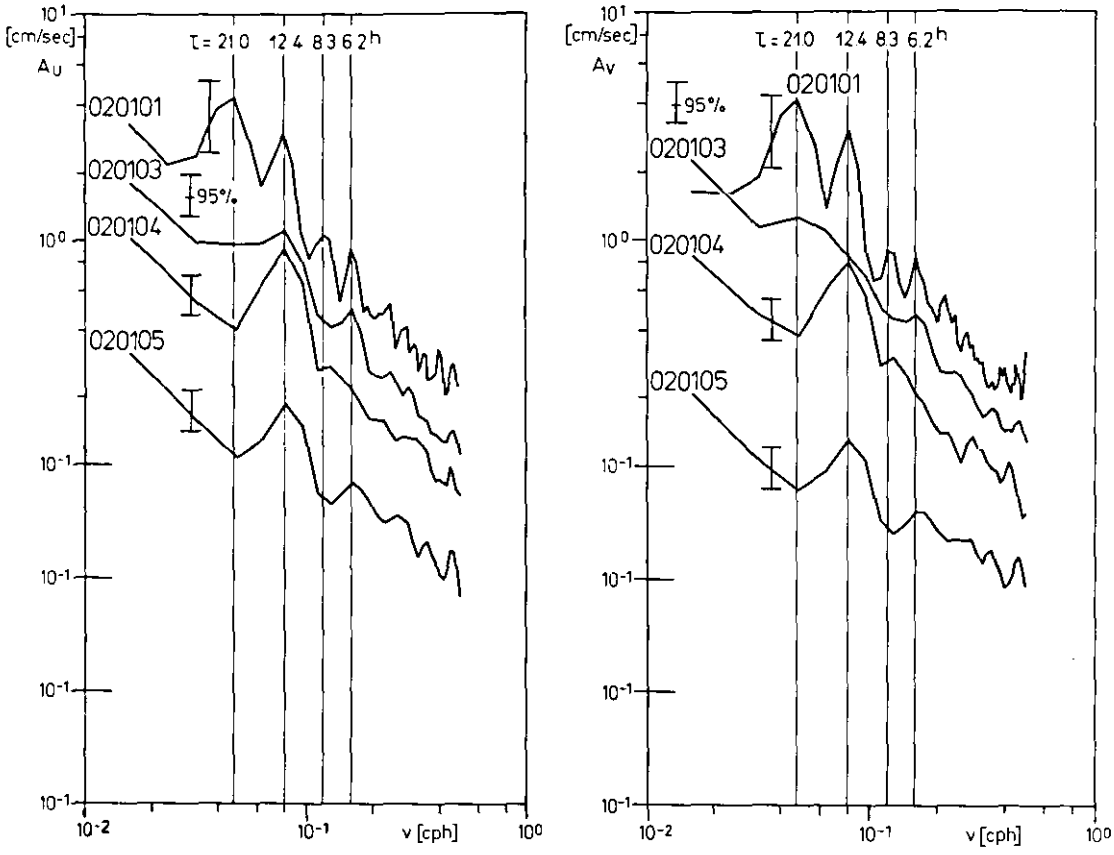

10¹ [cm/sec] Au
τ = 21.0 12.4 8.3 6.2 h
020101
020103
95%
020104
020105
10⁰
10⁻¹
10⁻²
ν [cph]
Av
020101
020103
020104
020105

Fig. 14

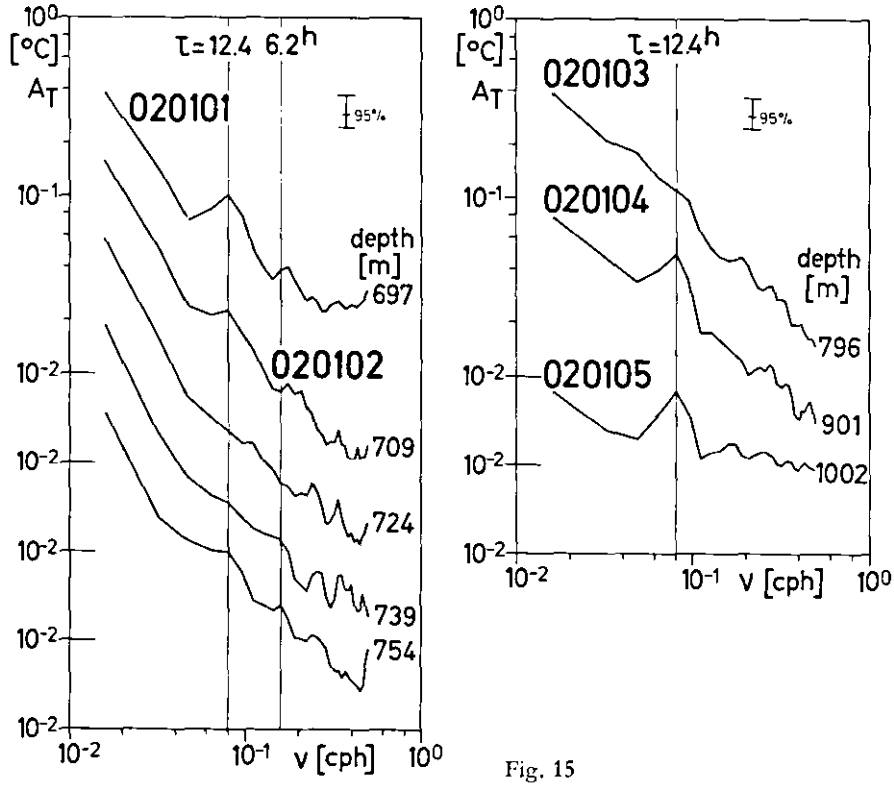

10⁰ [°C] AT
τ = 12.4 6.2 h
020101
95%
depth [m]
697
020102
709
724
739
754
10⁻¹
10⁻²
ν [cph]
τ = 12.4 h
020103
020104
020105
796
901
1002

Fig. 15

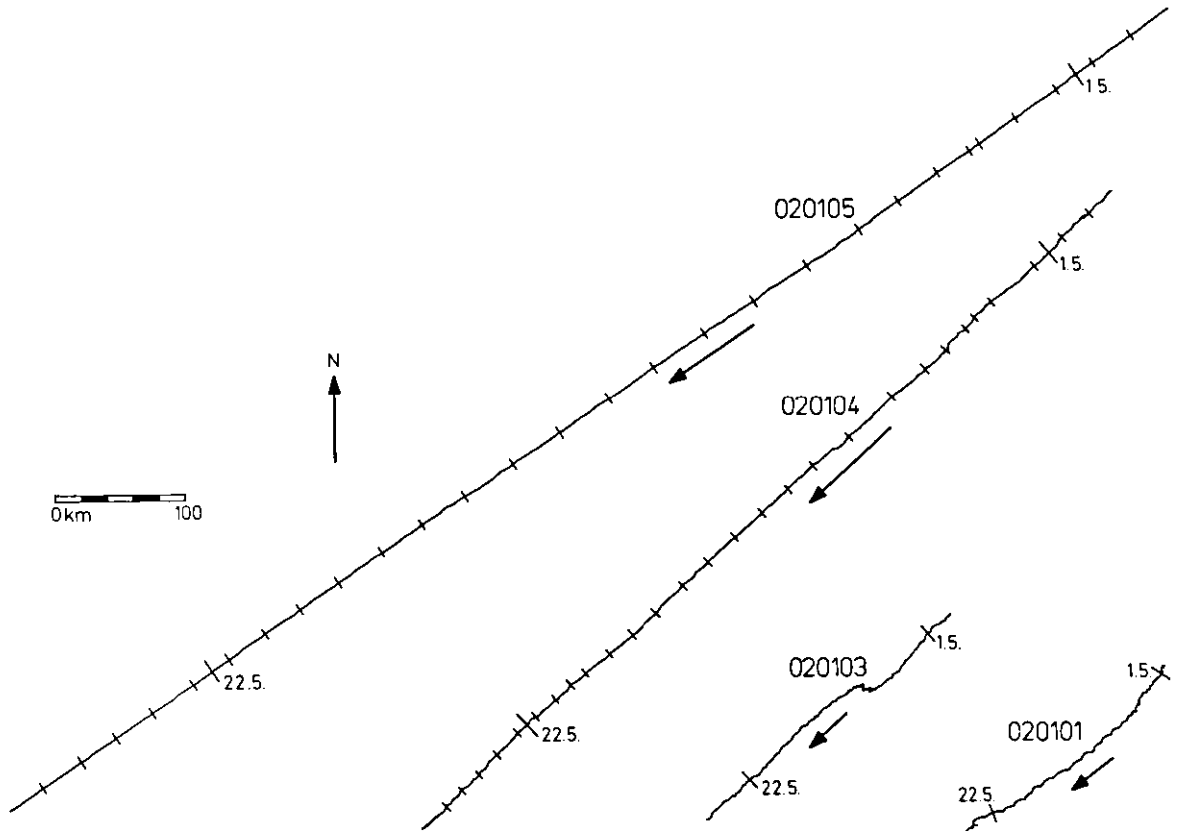

020105
020104
020103
020101
1.5.
22.5.
N
0km
100

Fig. 16

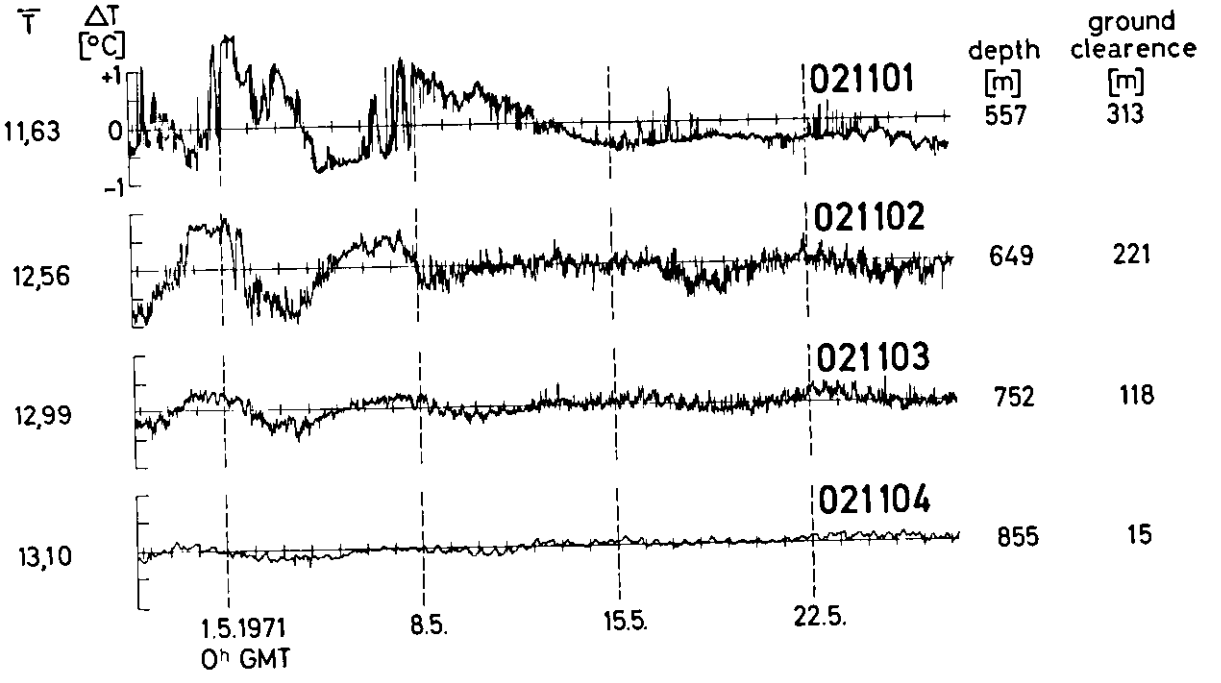

T̄
ΔT [°C]
+1
0
-1
021101
021102
021103
021104
depth [m]
ground clearence [m]
11,63
557
313
12,56
649
221
12,99
752
118
13,10
855
15
1.5.1971 0h GMT
8.5.
15.5.
22.5.

Fig. 17

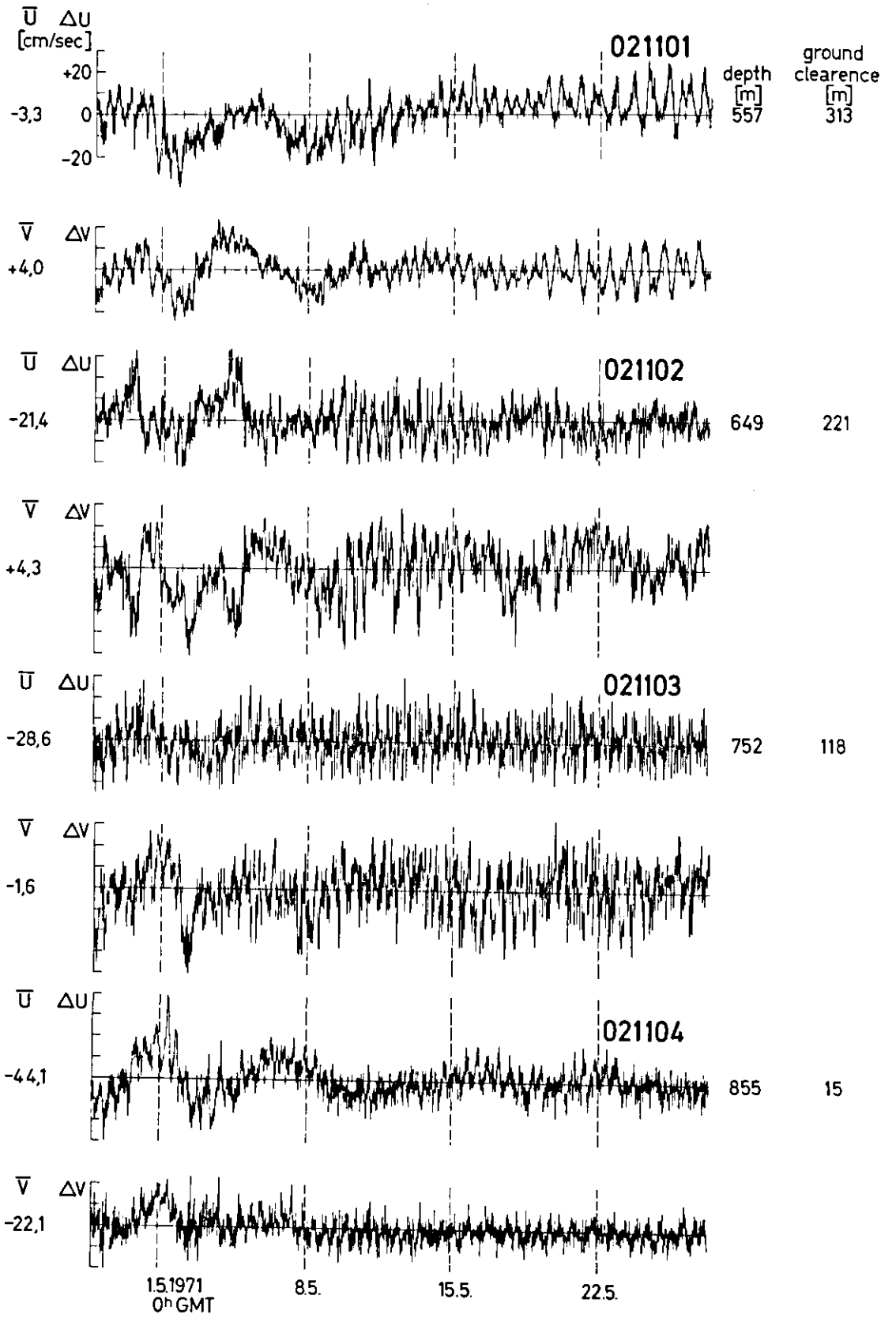

Ū ΔU
[cm/sec]
+20
-3,3 0
-20
021101
depth [m]
ground clearence [m]
557
313
V̄ ΔV
+4,0
Ū ΔU
021102
-21,4
649
221
V̄ ΔV
+4,3
Ū ΔU
021103
-28,6
752
118
V̄ ΔV
-1,6
Ū ΔU
021104
-44,1
855
15
V̄ ΔV
-22,1
1.5.1971
0h GMT
8.5.
15.5.
22.5.

Fig. 18

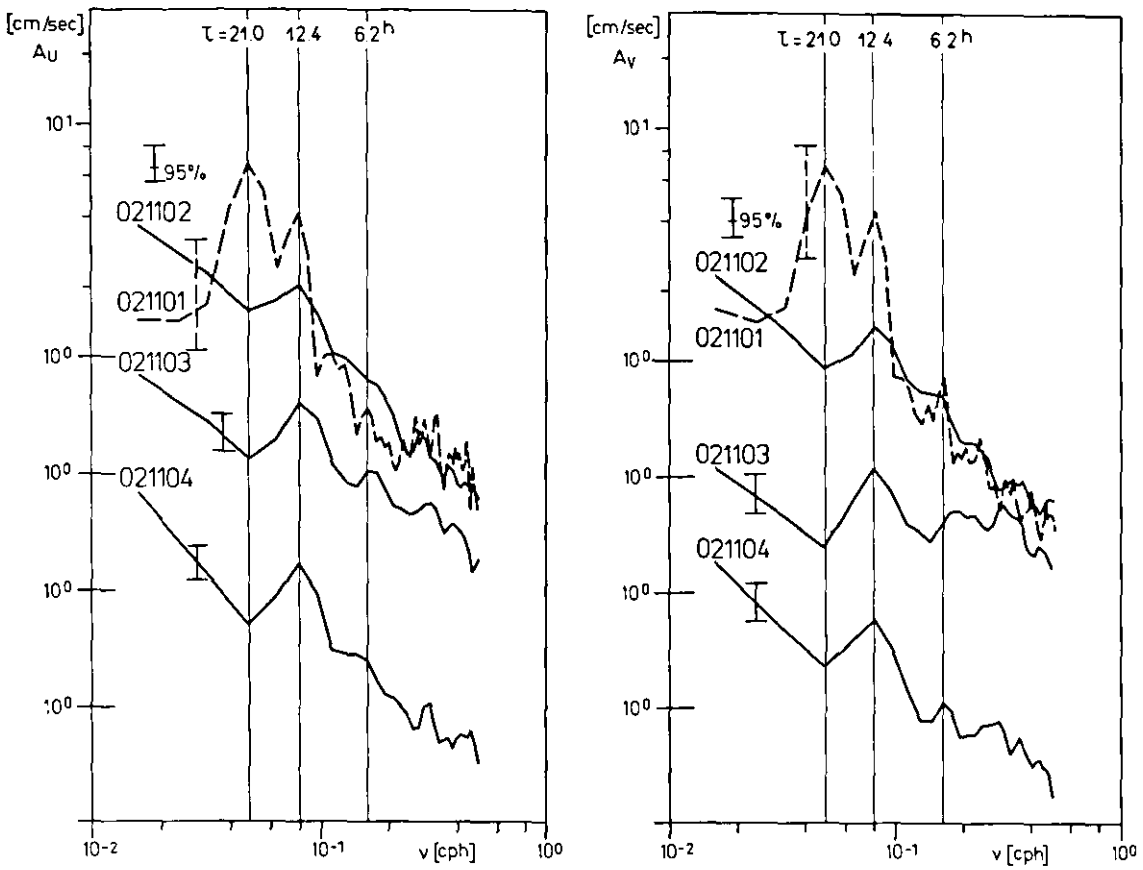

[cm/sec]
A_U
τ=21.0 12.4 6.2h
95%
021102
021101
021103
021104
10^1
10^0
10^{-1}
10^{-2}
ν [cph]
[cm/sec]
A_V
τ=21.0 12.4 6.2h
95%
021102
021101
021103
021104
10^1
10^0
10^{-1}
10^{-2}
ν [cph]

Fig. 19

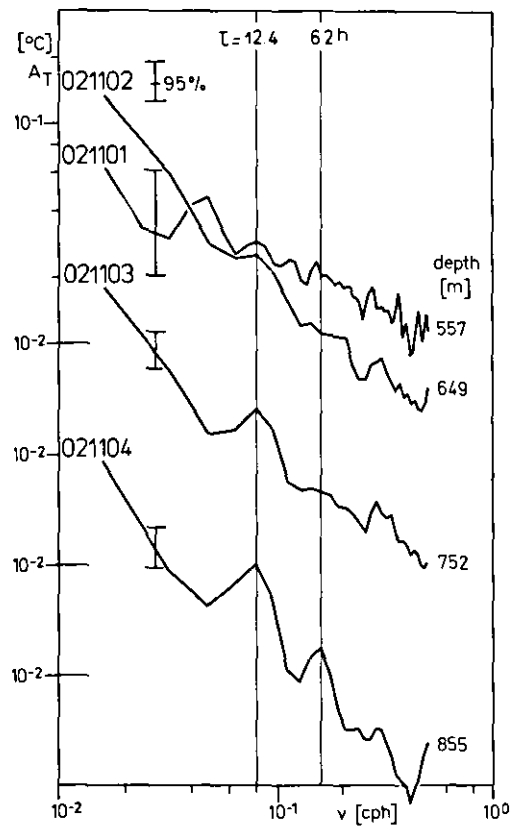

[°C]
A_T
τ=12.4 6.2h
021102
95%
021101
021103
021104
depth [m]
557
649
752
855
10^{-1}
10^{-2}
10^{-2}
10^{-2}
10^{-2}
10^{-2}
ν [cph]

Fig. 20

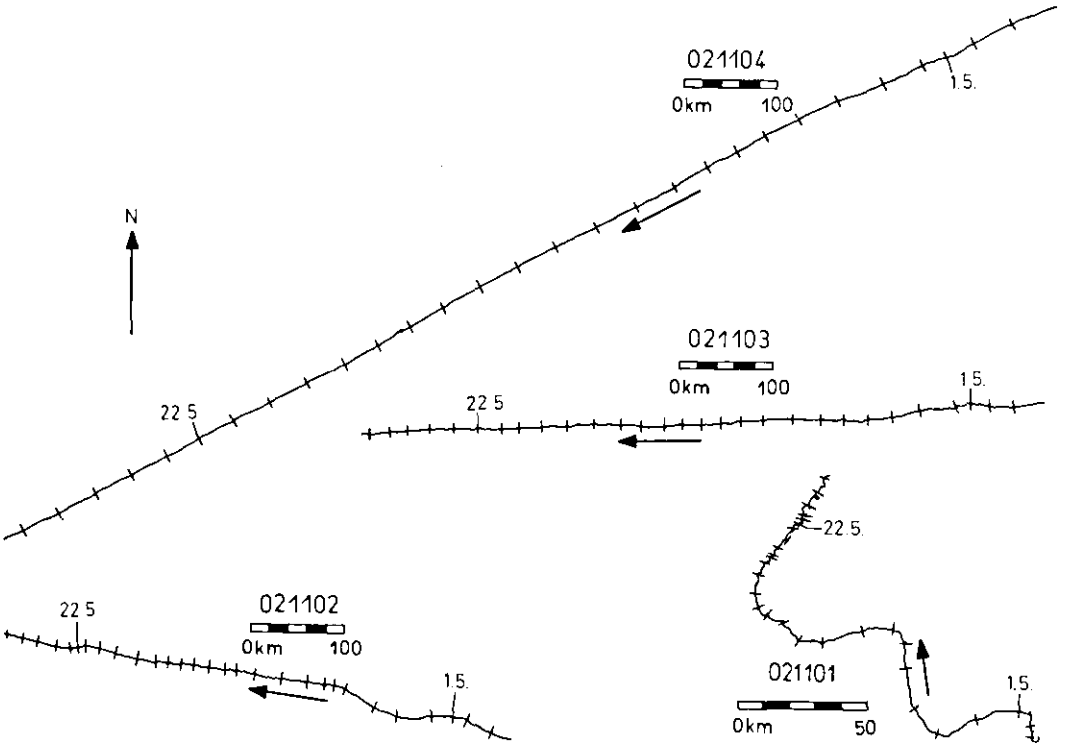

021104
0km 100
1.5.
N
22 5
021103
0km 100
22 5
1.5.
22 5.
022 5
021102
0km 100
1.5.
021101
0km 50
1.5.

Fig. 21

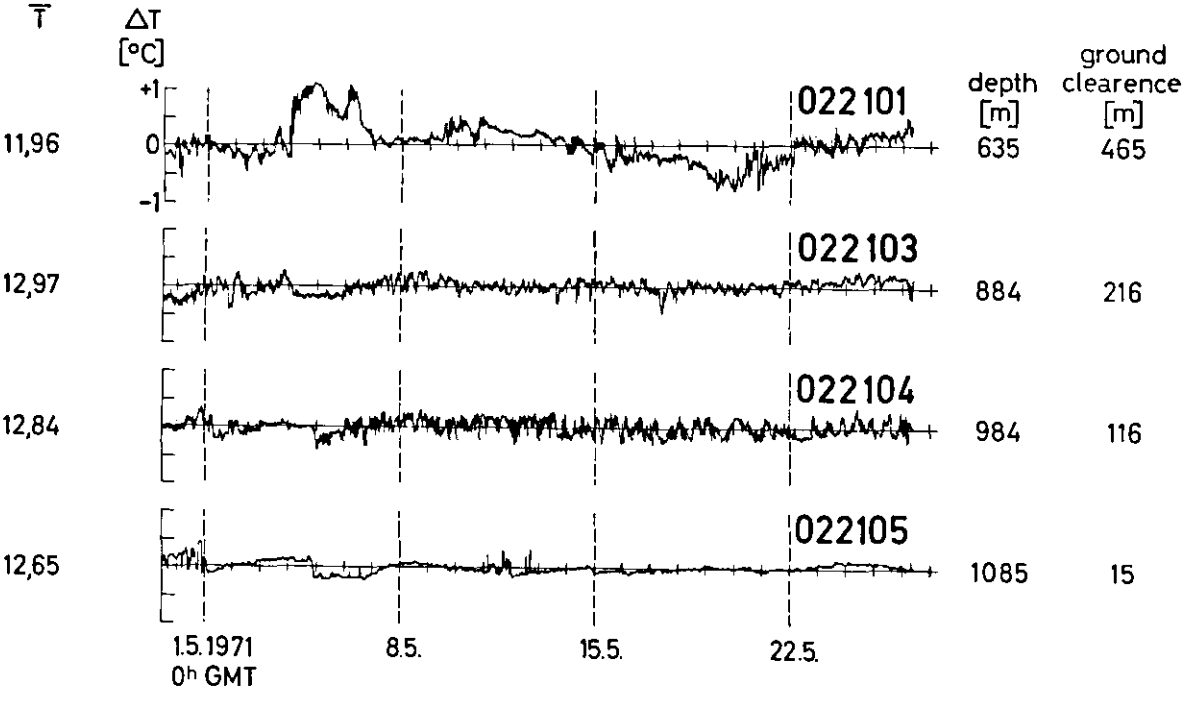

T̄
ΔT
[°C]
+1
0
-1
022101
022103
022104
022105
depth
[m]
ground
clearence
[m]
11,96
635
465
12,97
884
216
12,84
984
116
12,65
1085
15
1.5.1971
0h GMT
8.5.
15.5.
22.5.

Fig. 22

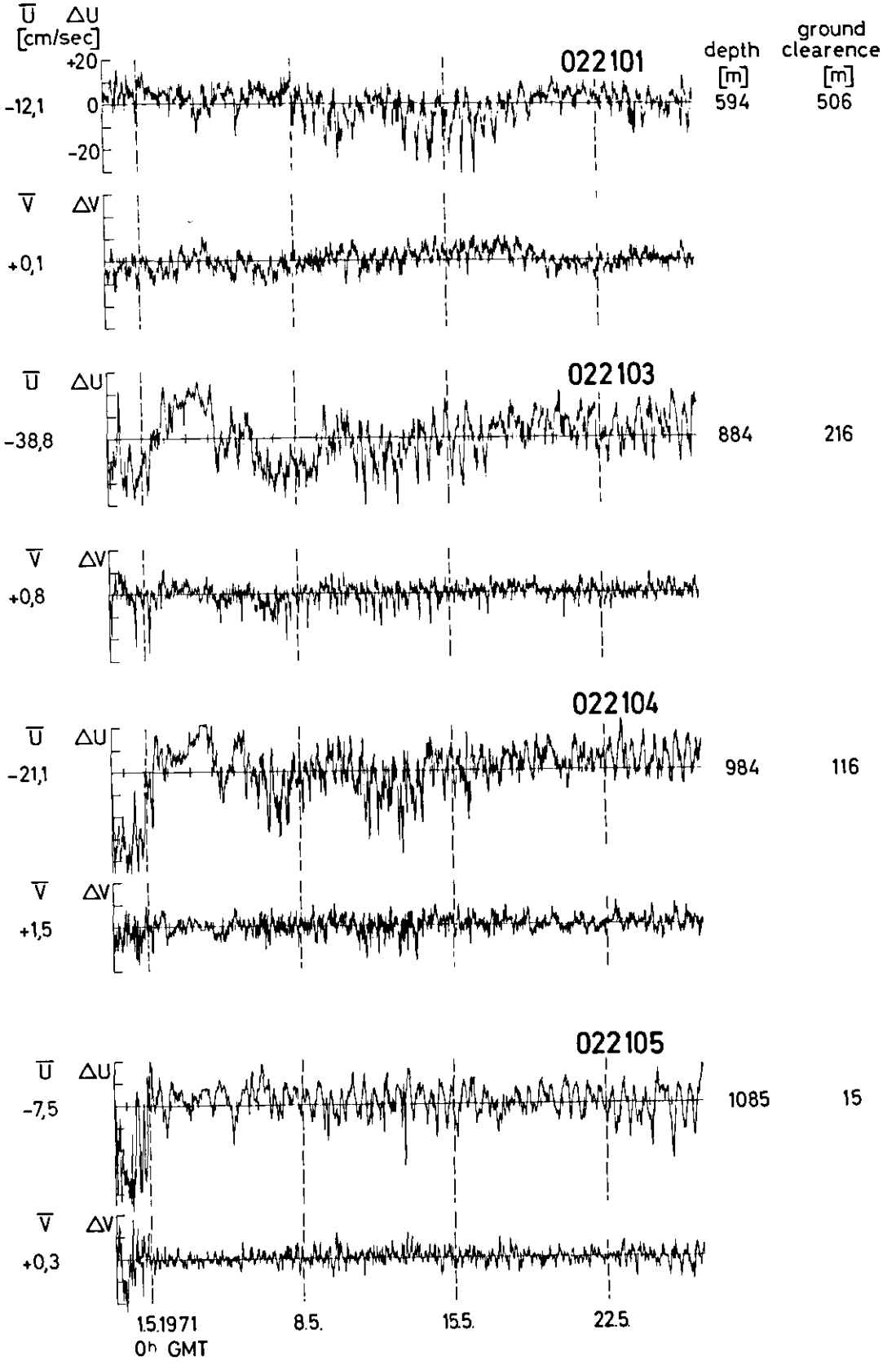
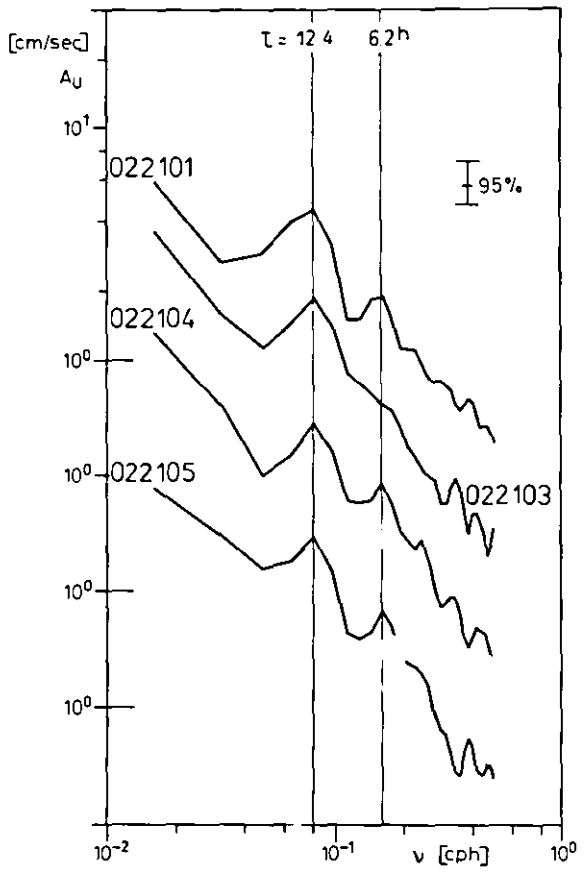

Ū ΔU
[cm/sec]
+20
0
-20
022101
depth [m]
ground clearence [m]
-12,1
594
506
V̄ ΔV
+0,1
Ū ΔU
022103
-38,8
884
216
V̄ ΔV
+0,8
022104
Ū ΔU
-21,1
984
116
V̄ ΔV
+1,5
022105
Ū ΔU
-7,5
1085
15
V̄ ΔV
+0,3
1.5.1971
0h GMT
8.5.
15.5.
22.5.

Fig. 23


[cm/sec]
A_U
τ = 12.4 6.2h
10^1
022101
95%
022104
10^0
10^0 022105
022103
10^0
10^0
10^{-2}
10^{-1}
ν [cph]
10^0

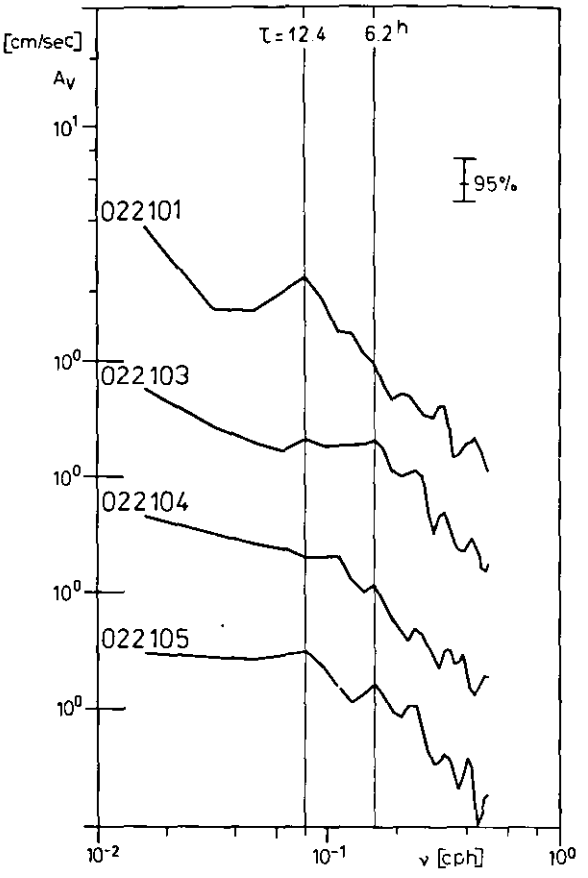

[cm/sec]
A_V
τ = 12.4 6.2h
10^1
95%
022101
10^0
022103
10^0
022104
10^0
022105
10^0
10^{-2}
10^{-1}
ν [cph]
10^0

Fig. 24

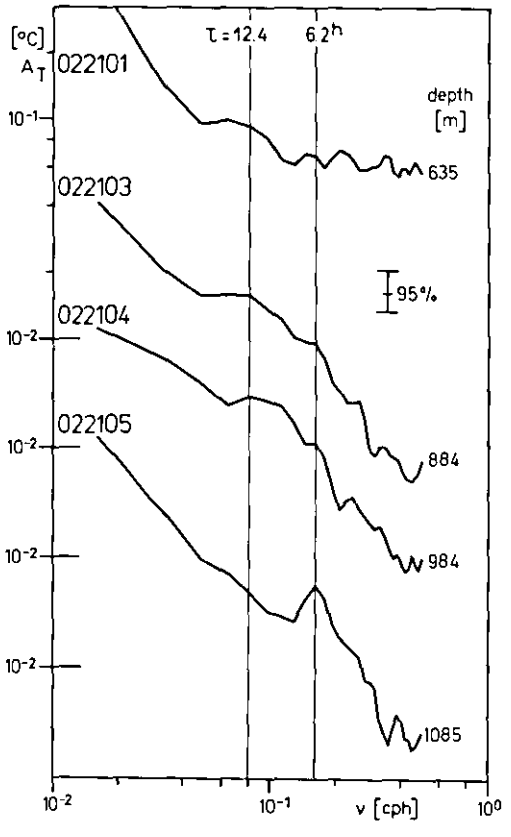

[°C]
A_T
τ = 12.4 6.2h
022101
depth
[m]
10^{-1}
635
022103
95%
022104
10^{-2}
884
022105
10^{-2}
984
10^{-2}
10^{-2}
1085
10^{-2}
10^{-1}
ν [cph]
10^0

Fig. 25

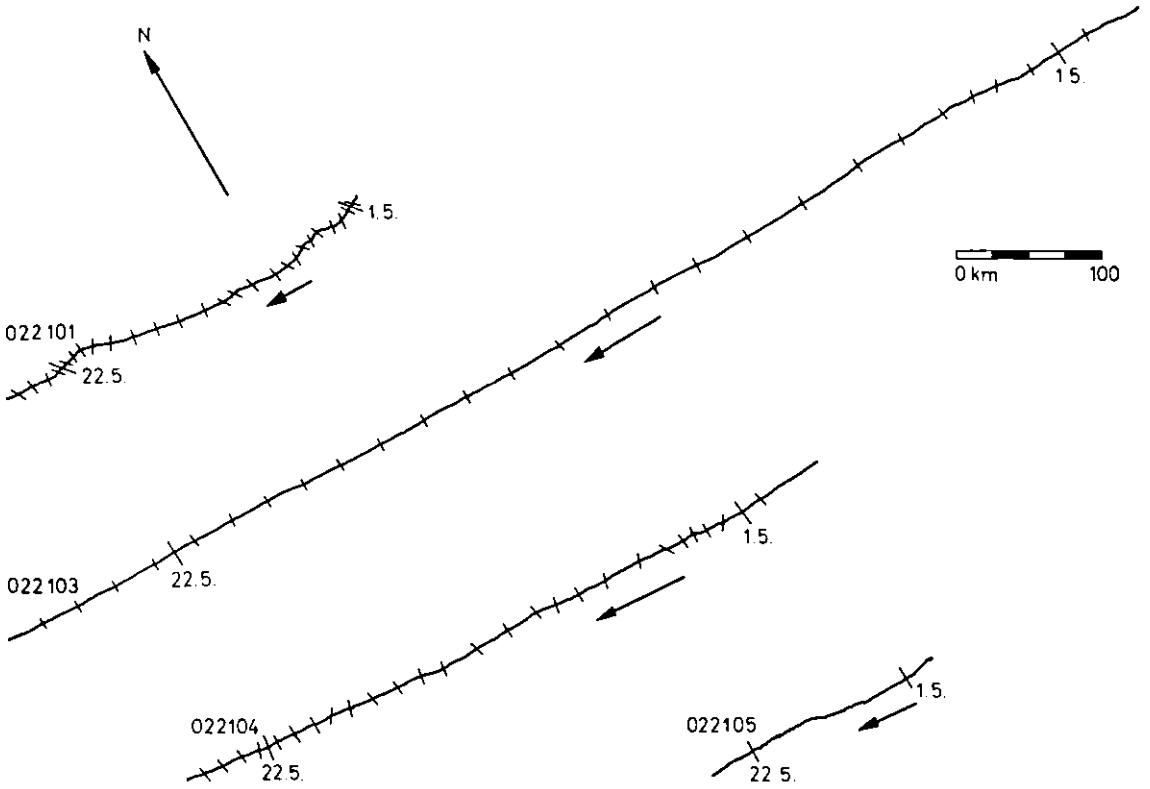

N
1.5.
1.5.
0 km
100
022101
22.5.
022103
22.5.
1.5.
022104
22.5.
022105
22 5.
1.5.

Fig. 26

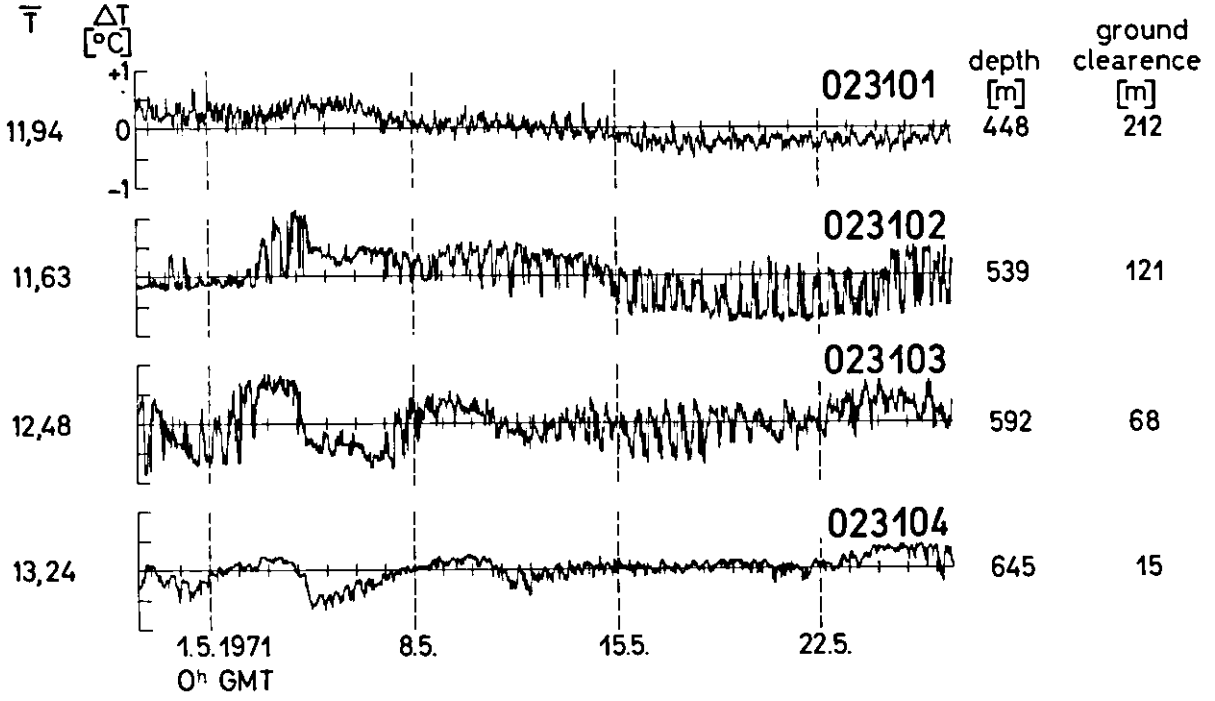

T
ΔT
[°C]
+1
0
-1
ground
depth
clearence
[m]
[m]
11,94
023101
448
212
11,63
023102
539
121
12,48
023103
592
68
13,24
023104
645
15
1.5.1971
0h GMT
8.5.
15.5.
22.5.

Fig. 27

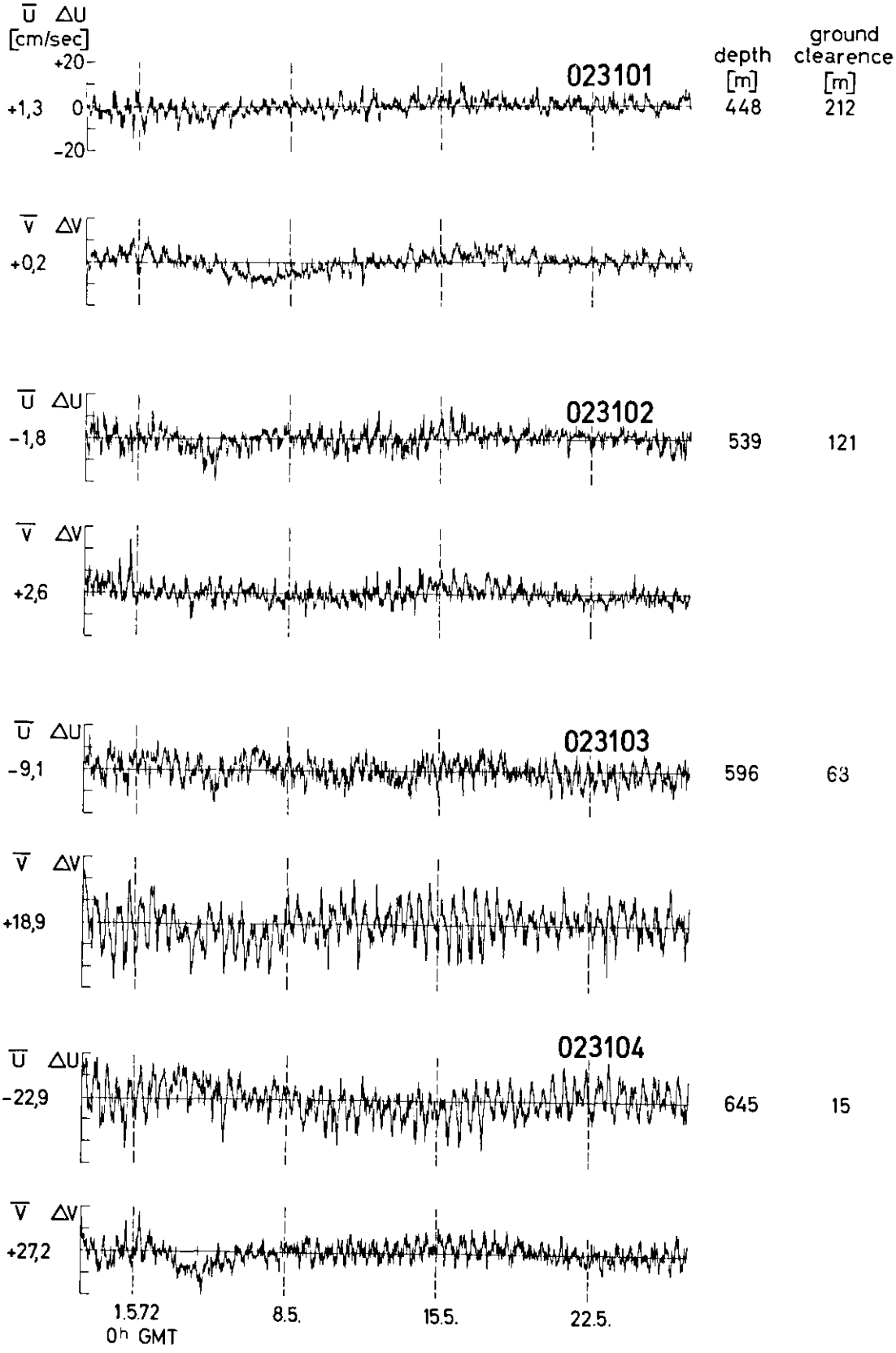
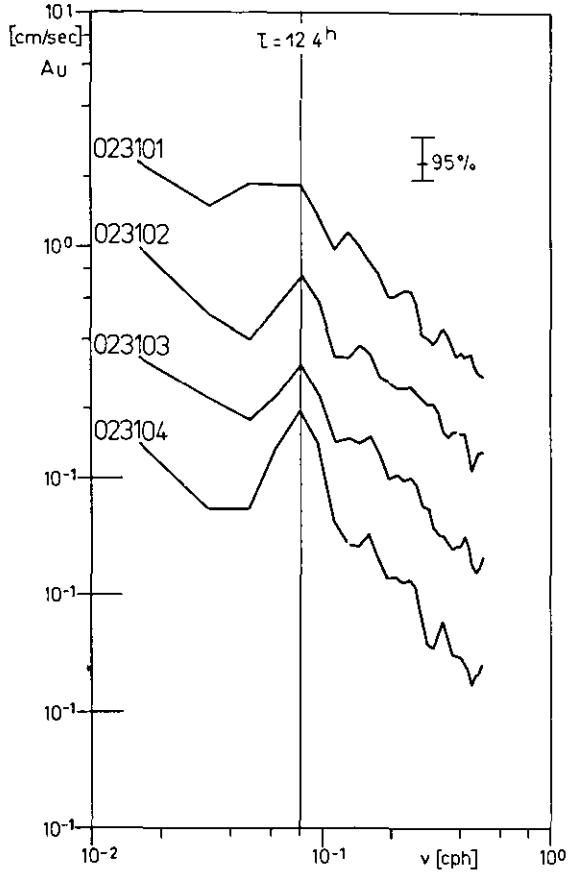

ū ΔU
[cm/sec]
+20
+1,3 0
-20
023101
depth [m] 448
ground clearence [m] 212
v̄ ΔV
+0,2
ū ΔU
-1,8
023102
539
121
v̄ ΔV
+2,6
ū ΔU
-9,1
023103
596
63
v̄ ΔV
+18,9
ū ΔU
-22,9
023104
645
15
v̄ ΔV
+27,2
1.5.72
0h GMT
8.5.
15.5.
22.5.

Fig. 28


10¹
[cm/sec]
Au
τ = 12.4 h
023101
95%
10⁰
023102
023103
023104
10⁻¹
10⁻¹
10⁻¹
10⁻¹
10⁻²
10⁻¹
ν [cph]
10⁰

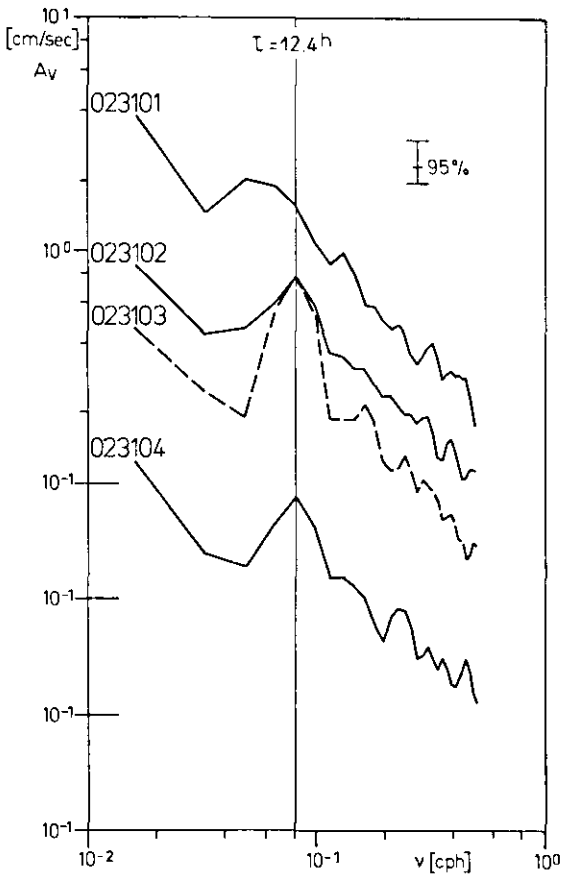

10¹
[cm/sec]
Av
τ = 12.4 h
023101
95%
10⁰
023102
023103
023104
10⁻¹
10⁻¹
10⁻¹
10⁻¹
10⁻²
10⁻¹
ν [cph]
10⁰

Fig. 29

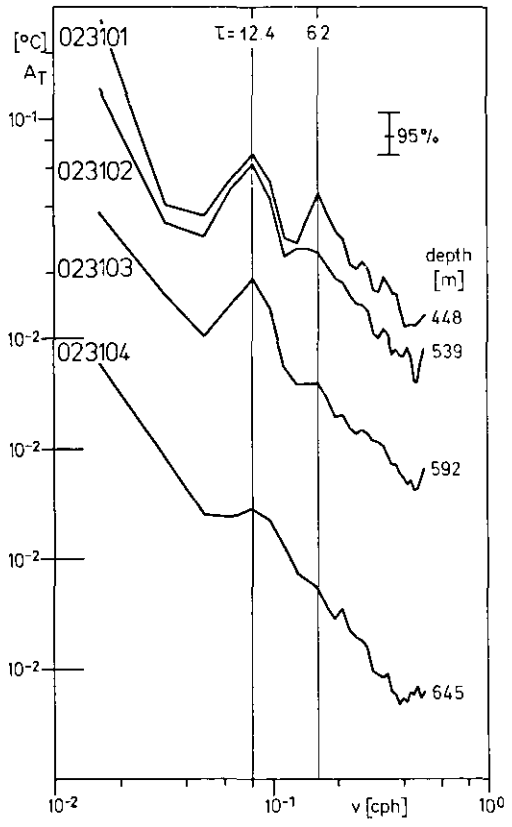

[°C]
AT
τ = 12.4
6.2
023101
95%
10⁻¹
023102
023103
depth
[m]
448
10⁻²
023104
539
10⁻²
592
10⁻²
10⁻²
645
10⁻²
10⁻¹
ν [cph]
10⁰

Fig. 30

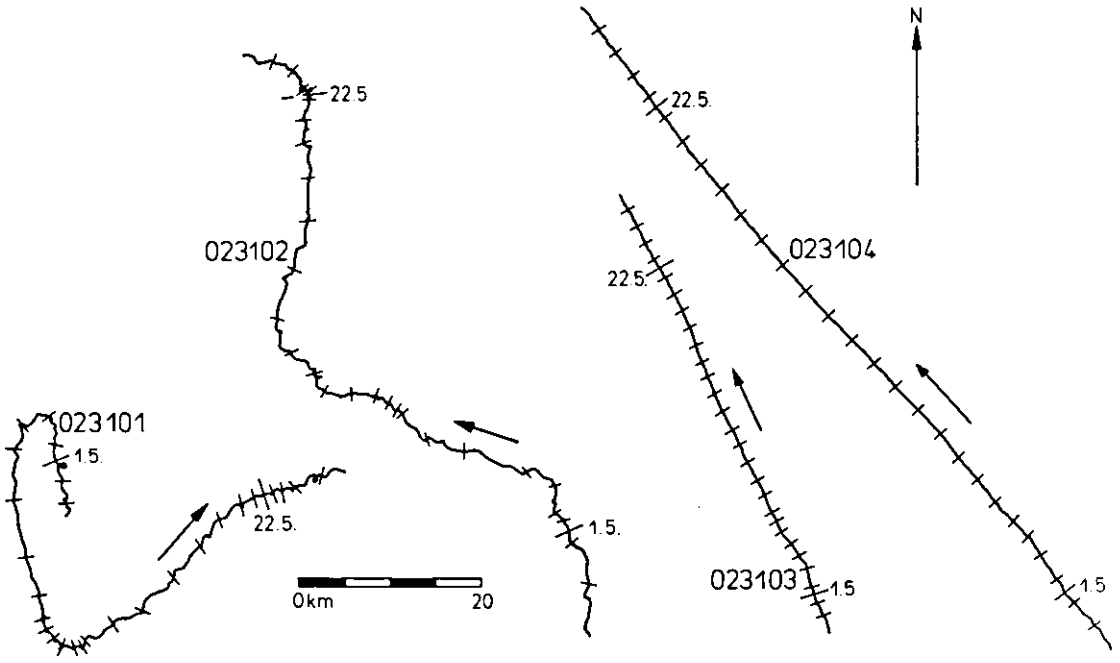

N
22.5
023102
023101
1.5
22.5
1.5
0km
20
22.5
023104
22.5
023103
1.5
1.5

Fig. 31

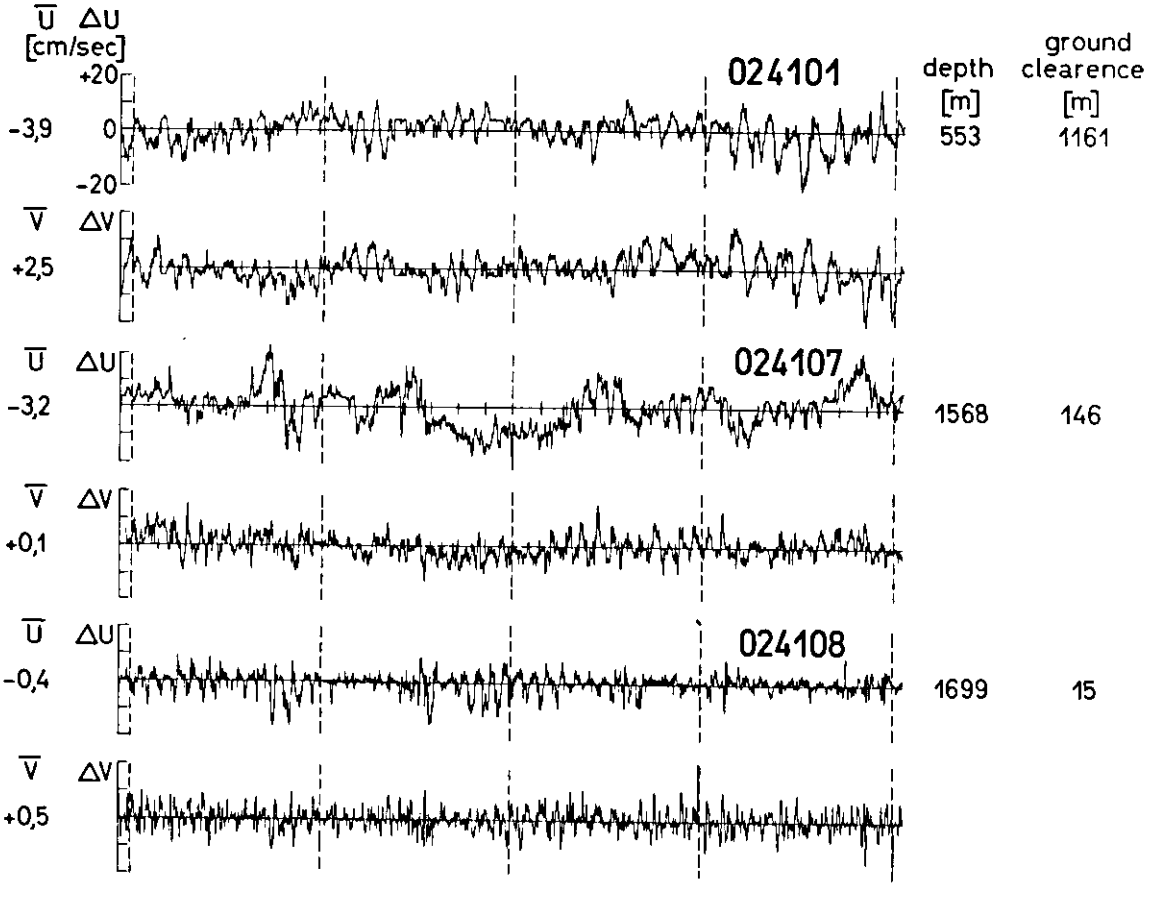

U ΔU
[cm/sec]
+20
-3,9
0
-20
024101
depth [m]
553
ground clearence [m]
1161
V ΔV
+2,5
U ΔU
-3,2
024107
1568
146
V ΔV
+0,1
U ΔU
-0,4
024108
1699
15
V ΔV
+0,5

Fig. 32

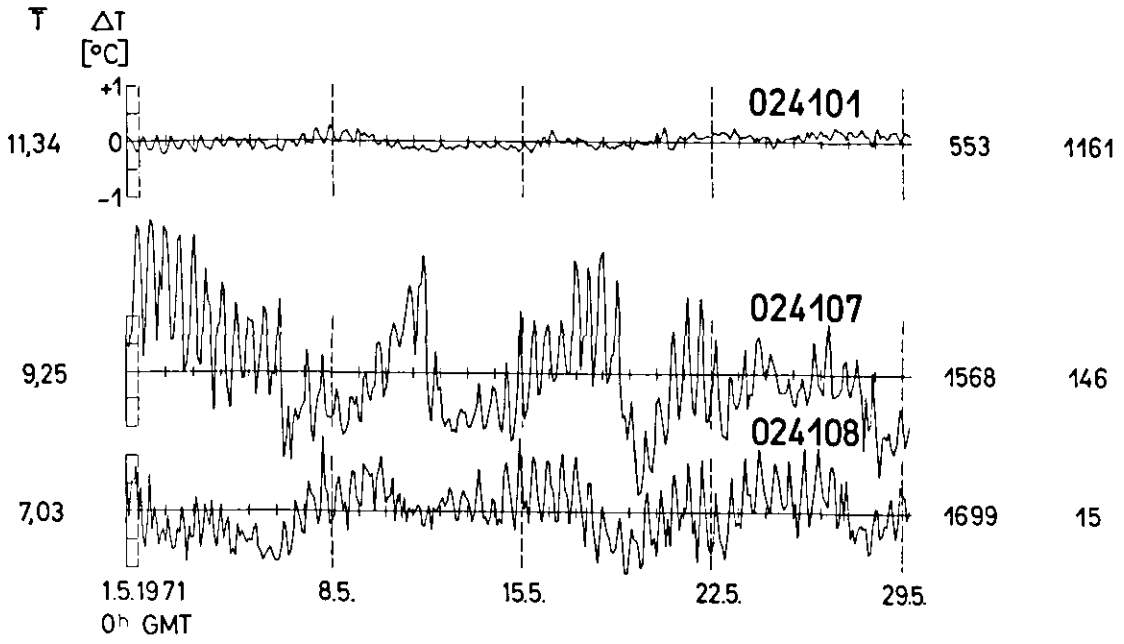

T
ΔT
[°C]
+1
0
-1
024101
11,34
553
1161
024107
9,25
1568
146
024108
7,03
1699
15
1.5.1971
0h GMT
8.5.
15.5.
22.5.
29.5.

Fig. 33

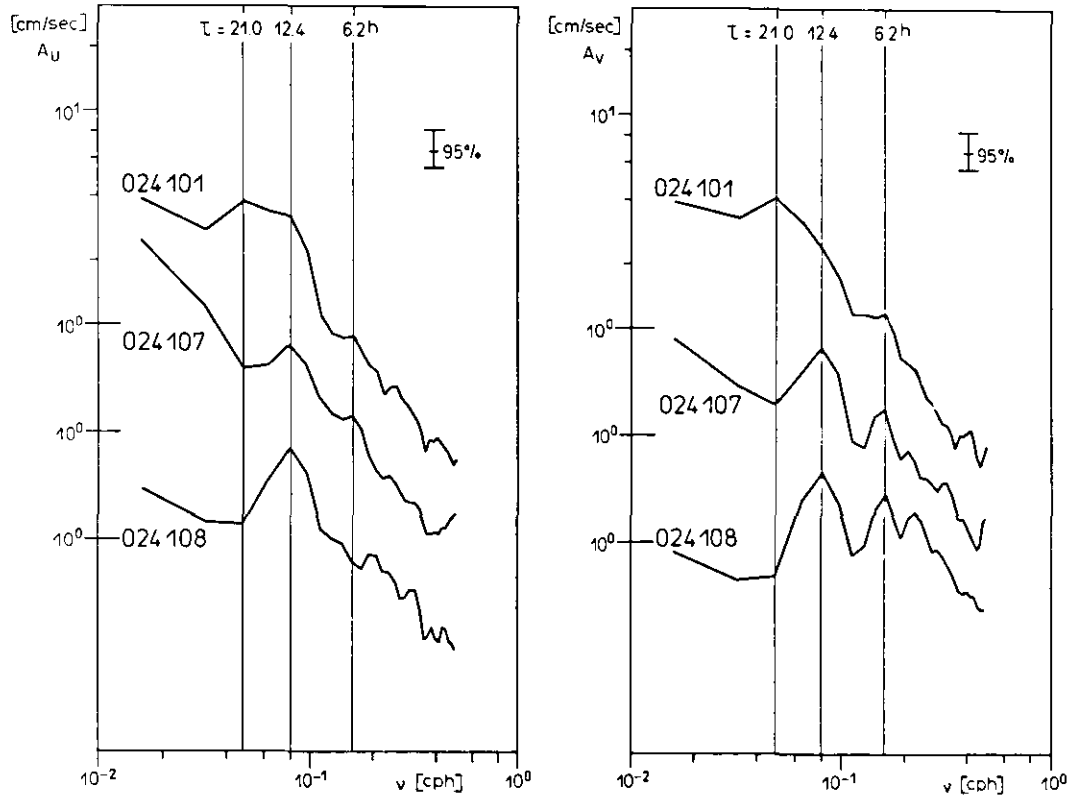

[cm/sec]
A_U
τ = 2.1.0 12.4 6.2h
95%
024101
024107
024108
10^1
10^0
10^{-2}
10^{-1}
ν [cph]
[cm/sec]
A_V
τ = 2.1.0 12.4 6.2h
95%
024101
024107
024108

Fig. 34

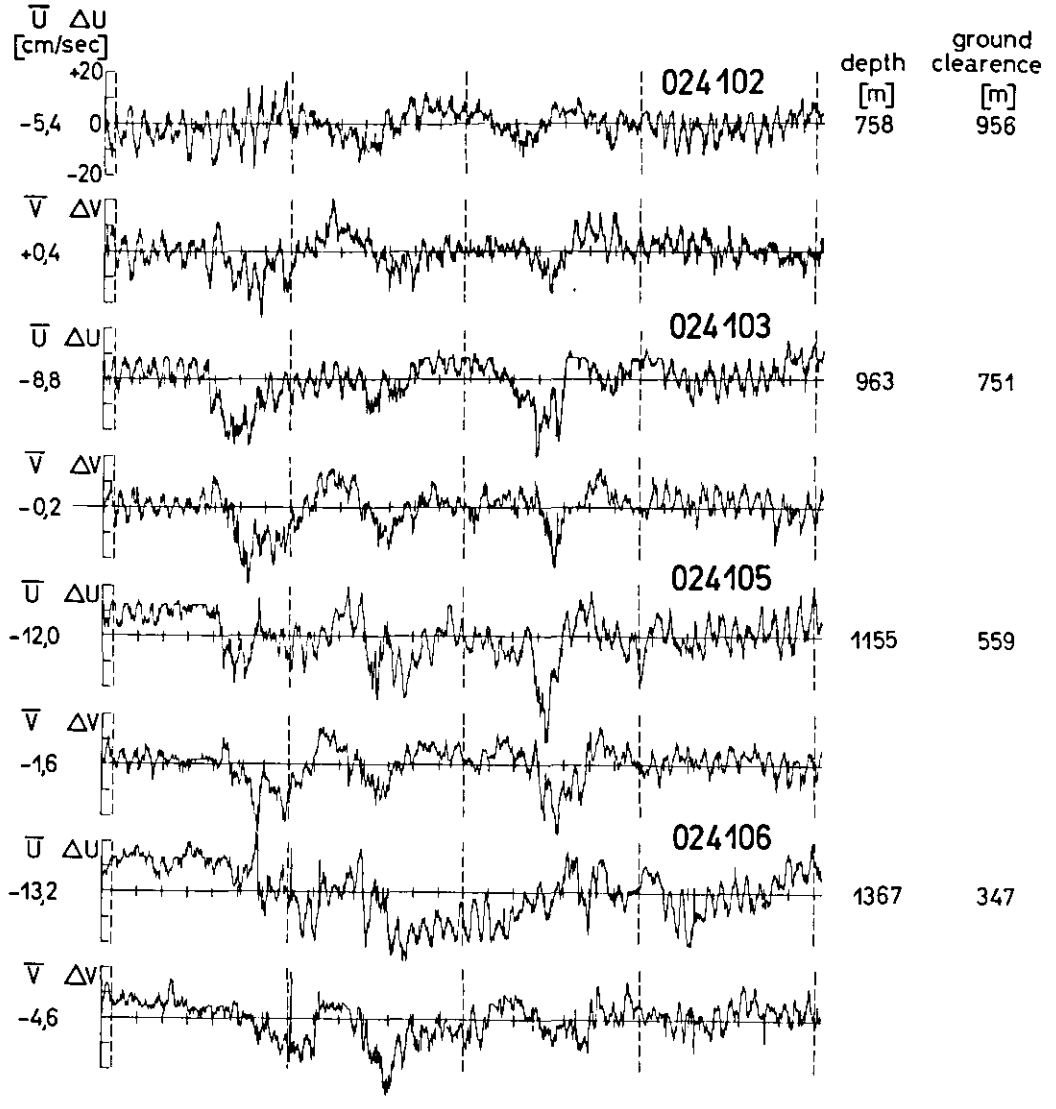

Ū ΔU
[cm/sec]
+20
-5,4
0
-20
024102
depth [m]
ground clearence [m]
758
956
V̄ ΔV
+0,4
024103
Ū ΔU
-8,8
963
751
V̄ ΔV
-0,2
024105
Ū ΔU
-12,0
1155
559
V̄ ΔV
-1,6
024106
Ū ΔU
-13,2
1367
347
V̄ ΔV
-4,6

Fig. 35

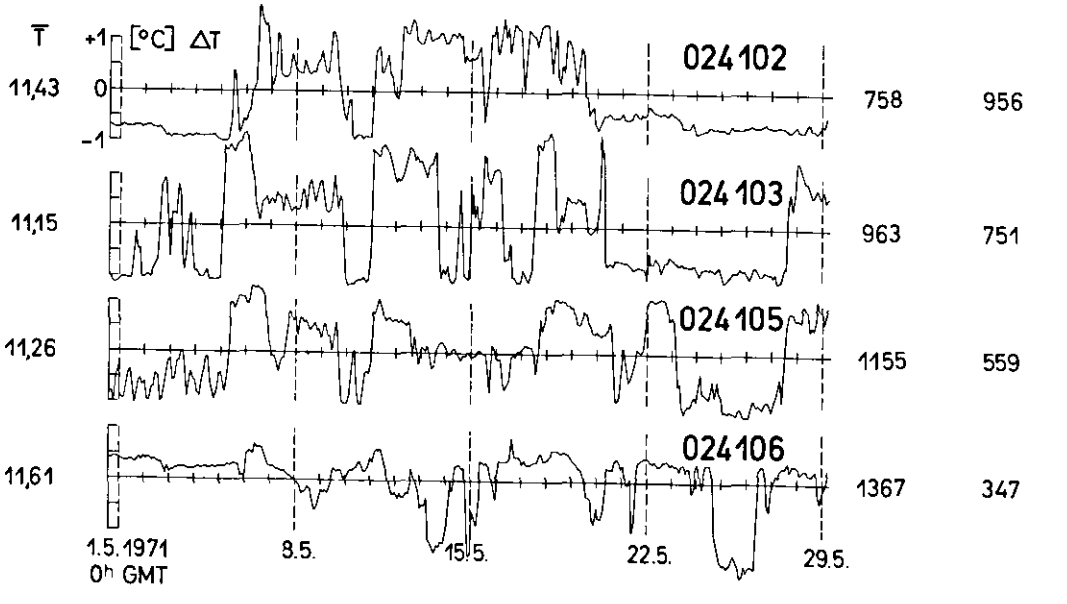

T̄ +1 [°C] ΔT
11,43
0
-1
024102
758
956
11,15
024103
963
751
11,26
024105
1155
559
11,61
024106
1367
347
1.5.1971
0h GMT
8.5.
15.5.
22.5.
29.5.

Fig. 36

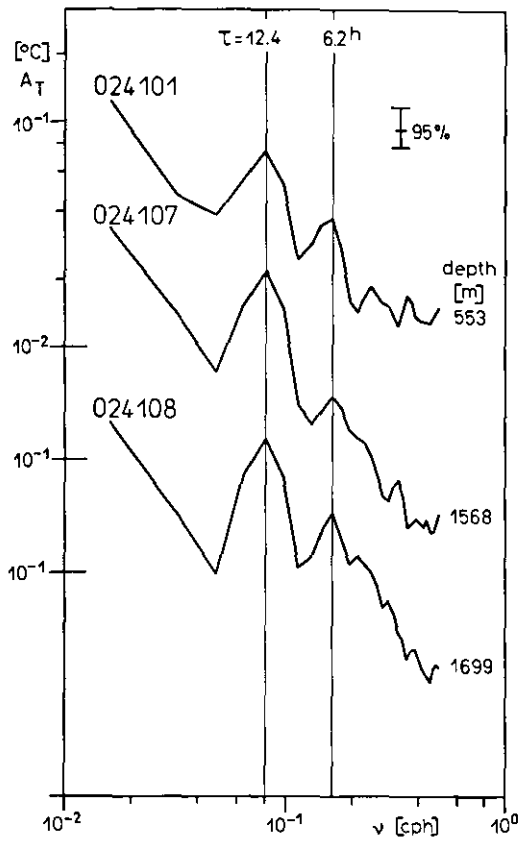


Fig. 37

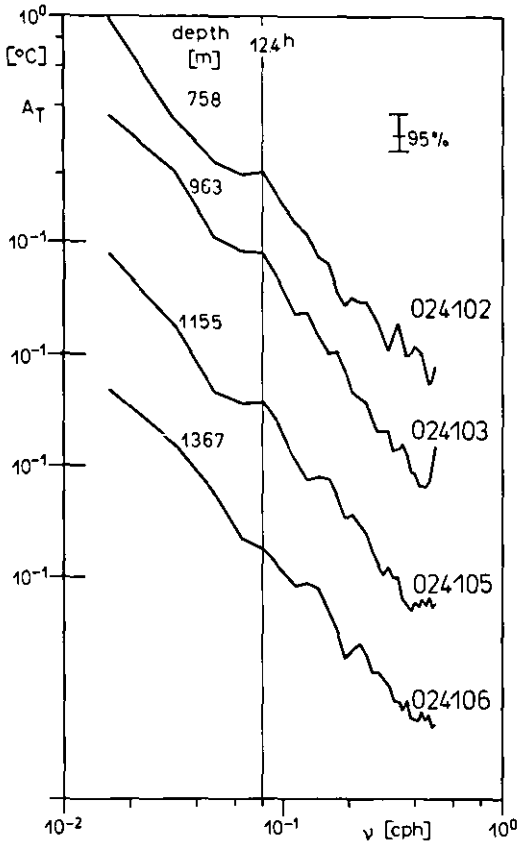


Fig. 38

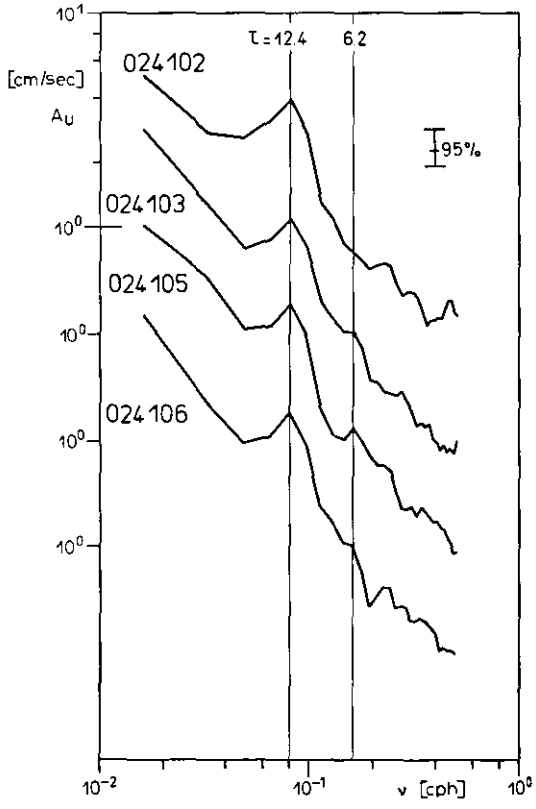
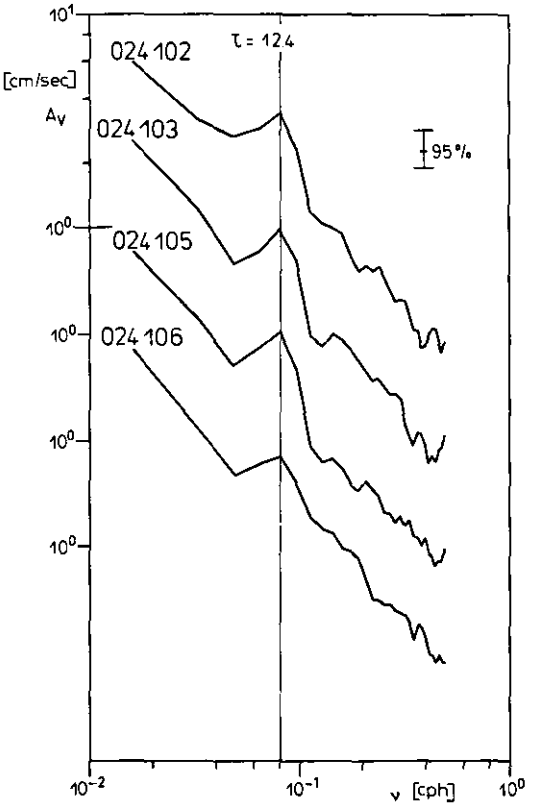


Fig. 39



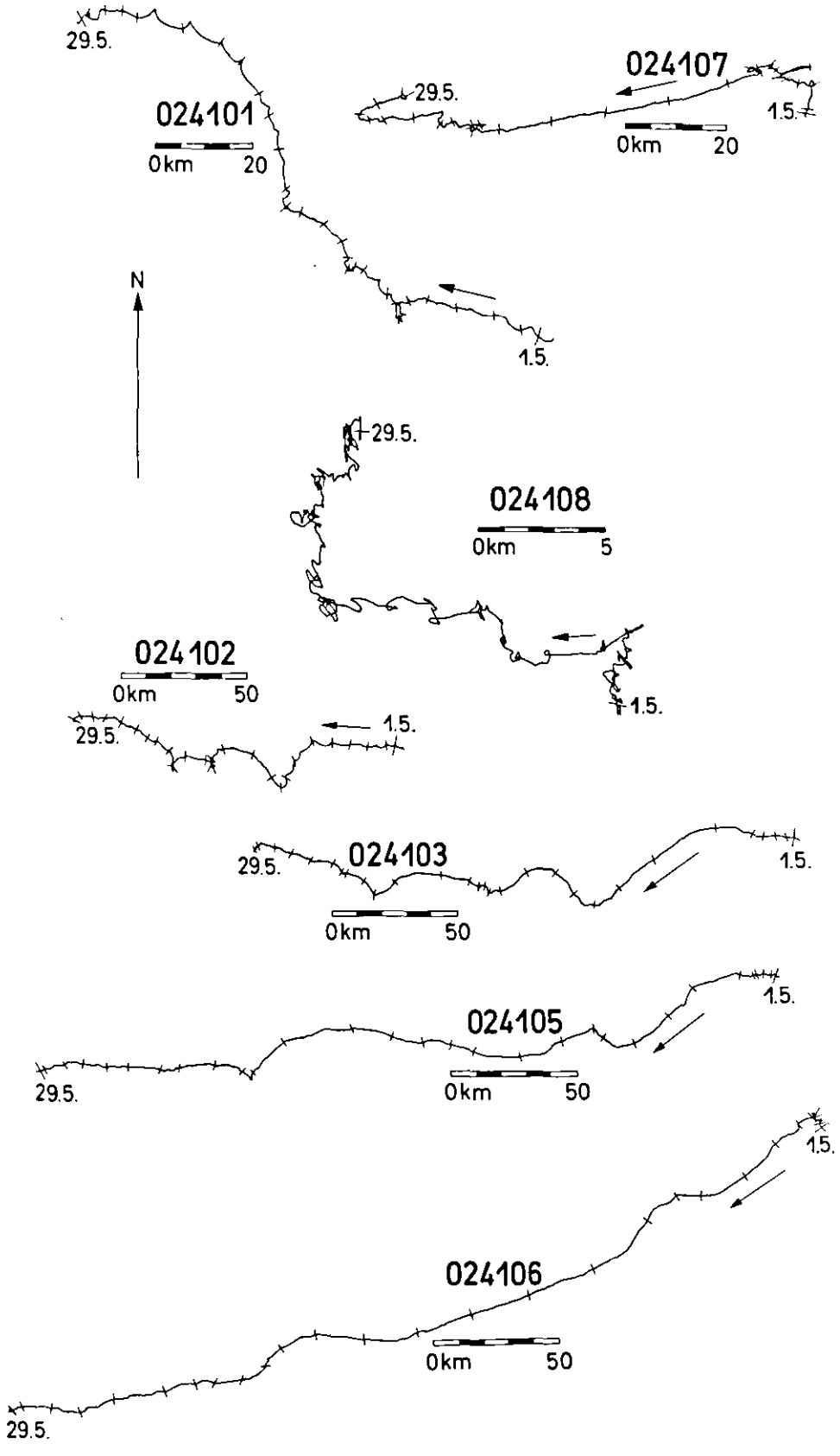

29.5.
024101
0km 20
024107
29.5.
1.5.
0km 20
N
1.5.
29.5.
024108
0km 5
1.5.
024102
0km 50
29.5.
1.5.
29.5.
024103
1.5.
0km 50
1.5.
024105
29.5.
0km 50
1.5.
024106
0km 50
29.5.

Fig. 40

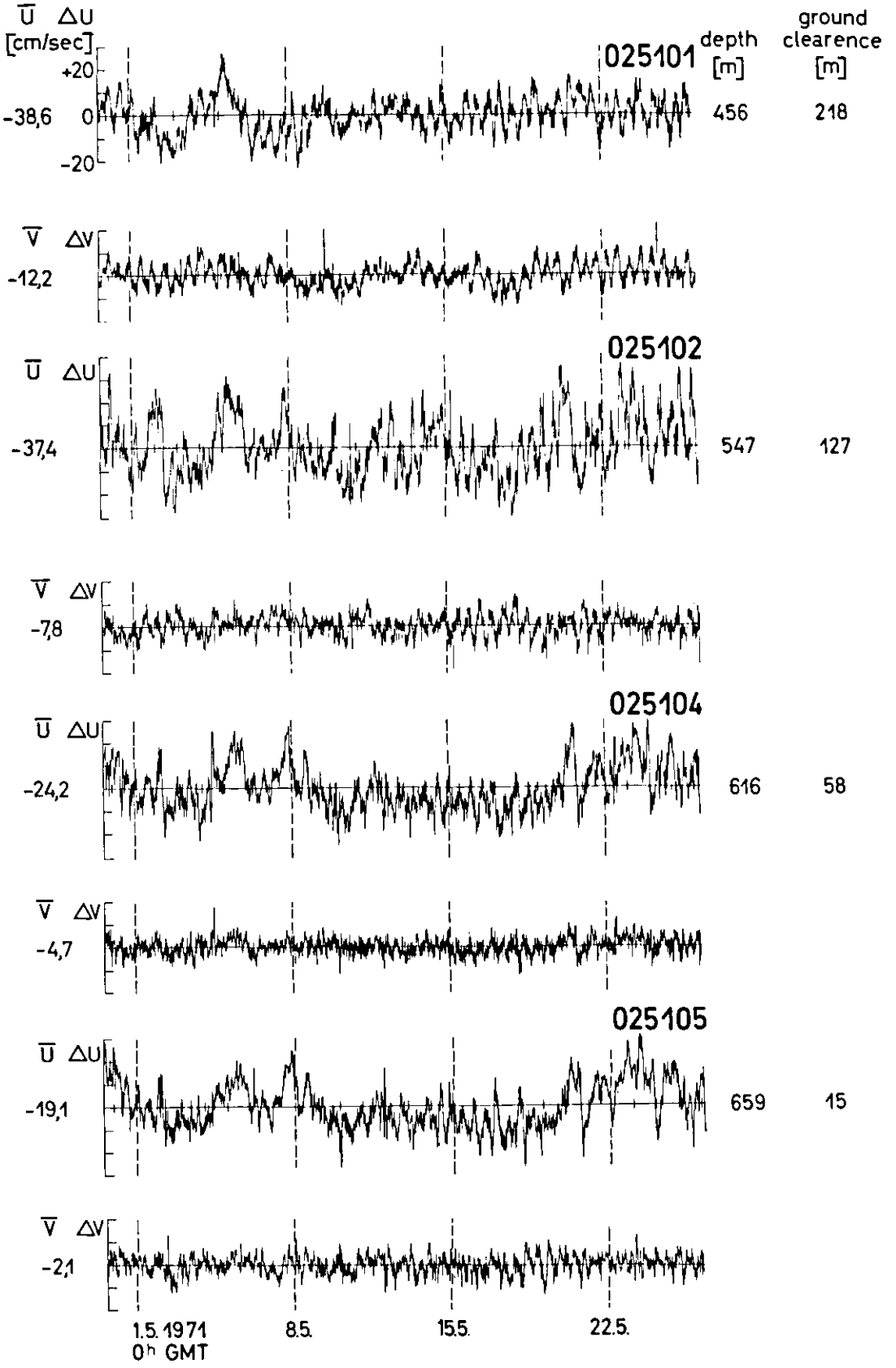

Ū ΔU
[cm/sec]
+20
-38,6 0
-20
025101
depth [m]
ground clearence [m]
456
218
V̄ ΔV
-12,2
025102
Ū ΔU
-37,4
547
127
V̄ ΔV
-7,8
025104
Ū ΔU
-24,2
616
58
V̄ ΔV
-4,7
025105
Ū ΔU
-19,1
659
15
V̄ ΔV
-2,1
1.5.1971
0h GMT
8.5.
15.5.
22.5.

Fig. 41

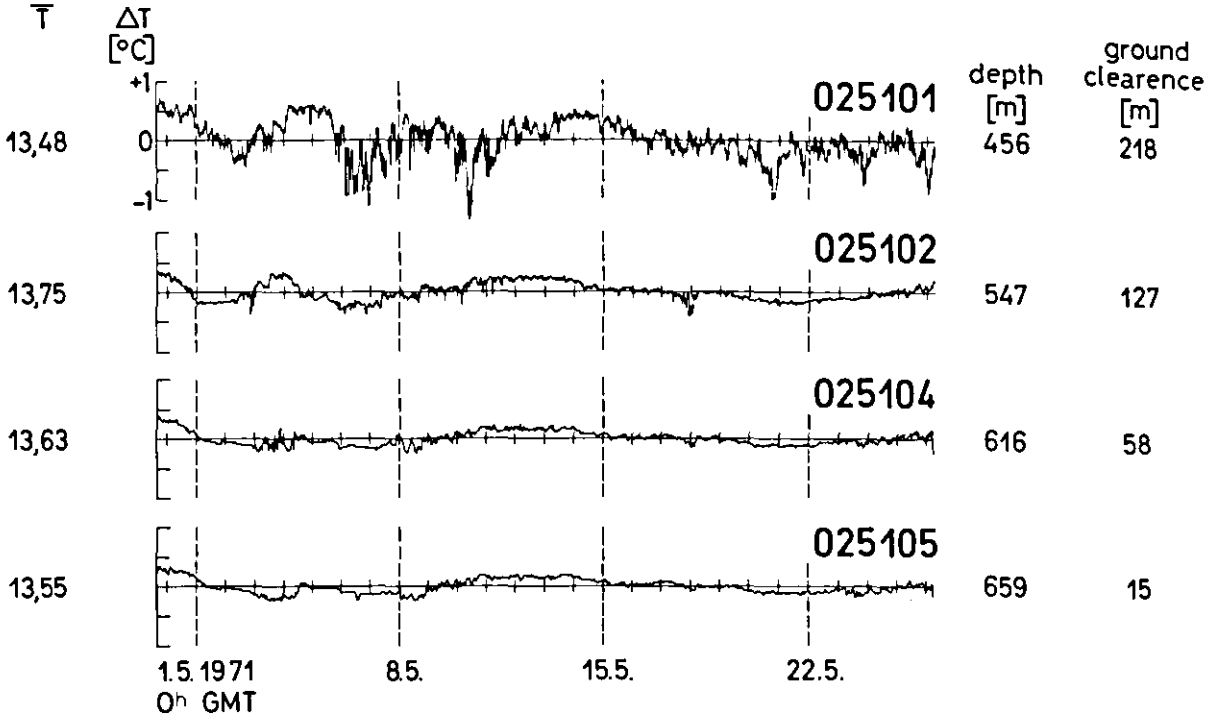

T̄
ΔT
[°C]
+1
0
-1
025101
025102
025104
025105
depth
[m]
ground
clearence
[m]
13,48
456
218
13,75
547
127
13,63
616
58
13,55
659
15
1.5.1971
0h GMT
8.5.
15.5.
22.5.

Fig. 42

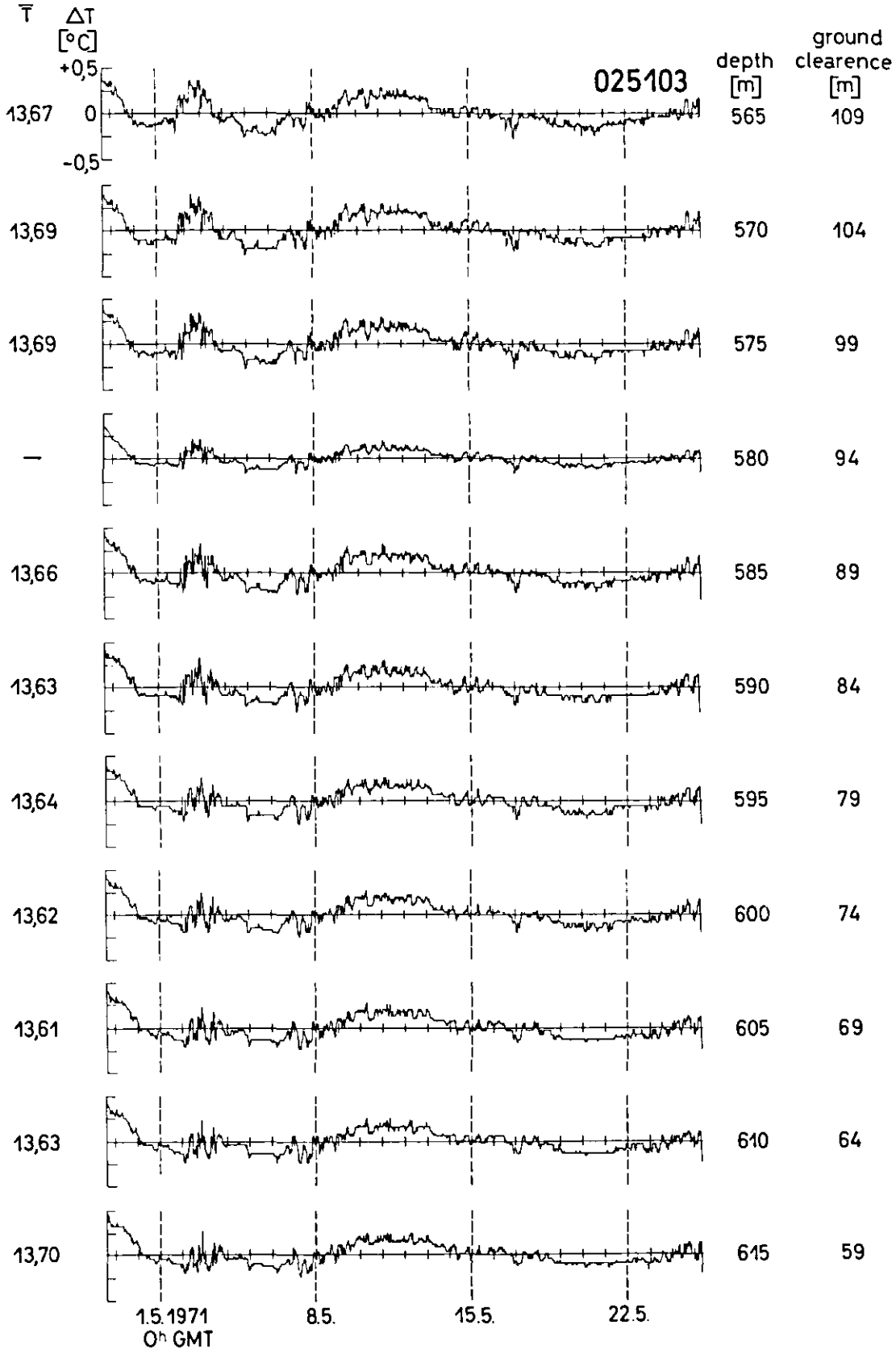

T̄
ΔT [°C]
+0,5
0
-0,5
025103
depth [m]
ground clearence [m]
13,67 565 109
13,69 570 104
13,69 575 99
— 580 94
13,66 585 89
13,63 590 84
13,64 595 79
13,62 600 74
13,61 605 69
13,63 610 64
13,70 615 59
1.5.1971 0h GMT
8.5.
15.5.
22.5.

Fig. 43

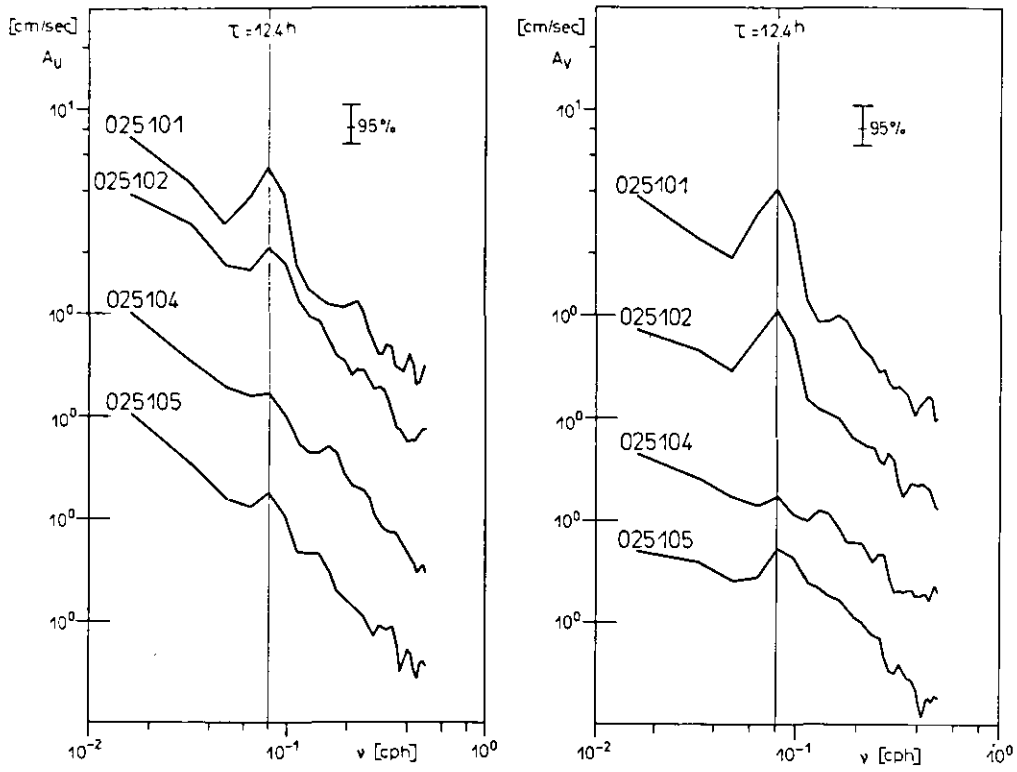

[cm/sec]
A_u
τ = 12.4 h
95%
025101
025102
025104
025105
10^1
10^0
10^{-2}
10^{-1}
ν [cph]
10^0
[cm/sec]
A_v
τ = 12.4 h
95%
025101
025102
025104
025105
10^1
10^0
10^{-2}
10^{-1}
ν [cph]
10^0

Fig. 44

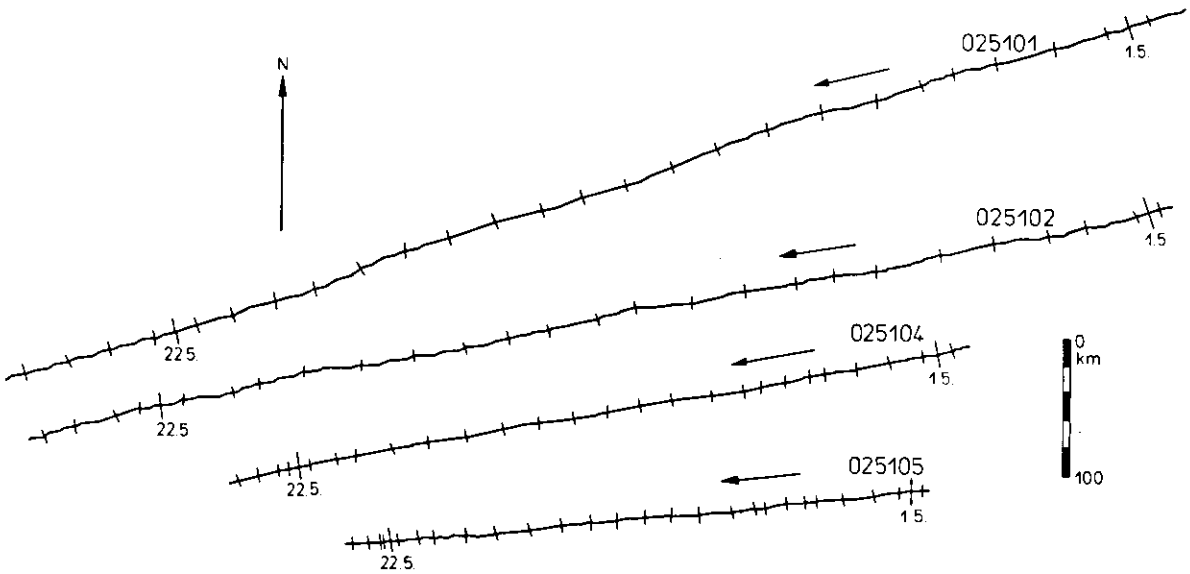

N
025101
1.5.
025102
1.5.
025104
1.5.
025105
1.5.
22.5.
22.5.
22.5.
22.5.
0
km
100

Fig. 45