THERMAL MAPPING FOR A HIGHWAY GRITTING NETWORK

by

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VOLUME II

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VOLUME 2

APPENDICES

APPENDIX 1

DETAILS OF MAPPING ROUTES

ROUTE 1

File reference: FULLx/DEVxx(1988/89); MOSx/DVxx(1989/90); MSx(1990/91)

Start: Derbyshire boundary (A57)

Moscar Top Sensor (A57)

Past junction with Rivelin Valley Road (A57)

Crosspool (A57)

Broomhill (A57)

Past university (Western Bank, A57)

Brookhill roundabout

Netherthorpe Road

Hoyle Street

Infirmary Road (B6079)

Middlewood Road (B6079)

Leppings Lane (B6079)

Right at roundabout along A61

Penistone Road (A61)

Hillfoot sensor (A61)

Shalesmoor (A61)

Moorfields (A61)

Gibraltar Street (A61)

Left at West Bar roundabout

Bridge Street

Wicker

Savile Street

Right into Sutherland Street

Left onto Attercliffe Road (A6178)

Attercliffe Common (A6178)

Sheffield Road (A6178)

Tinsley sensor (opposite side of road, A6178)

Twice round roundabout, M1 junction 34(S)

Shepcote Lane

Left onto Greenland Road (A6102)

Prince of Wales Road (A6102)

Parkway roundabout (straight on)

Prince of Wales Road sensor (A6102)

Across gap in central reservation (75m after sensor)

Left at roundabout onto Parkway

Sheffield Parkway (A57)

Twice round Park Square roundabout

Broad Street

Finish: Road bends left sign

Distance: 1918 counts/38.4km

Time: 40-45 minutes

ROUTE 2

File reference: ECCx

Start: Sheffield/Rotherham boundary A6135

Chapletown (A6135)

Ecclesfield (A6135)

Barnsley Road (A6135)

Rutland Road (B6070)

Left onto Penistone Road (A61)

Hoyle Street

Netherthorpe Road

Upper Hanover Street (A6134)

Hanover Way

Right at roundabout onto Ecclesall Road (A625)

Ecclesall Road South (A625)

Hathersage Road (A625)

Finish: Derbyshire boundary (A625)

Distance: 1288 counts/25.8km

Time: 28-32 minutes

ROUTE 3

File reference: RIVx

Start: Junction Rivelin Valley Road (A6101) with A57

A6101

Holme Lane

Loxley New Road

Holme Lane

Bradfield Road

Owlerton Green

Left onto Penistone Road (A61)

Right at roundabout into Herries Road

Herries Road (A6102)

Owler Lane (A6102)

Upwell Street (A6102)

Hawke Street (A6102)

Janson Street (A6102)

Left onto Attercliffe Road (A6178)

Broughton Lane (A6102)

Greenland Road (A6102)

Prince of Wales Road (A6102)

Ridgeway Road (A6102)

Norton Avenue (A6102)

Bochum Parkway (A6102)

Greenhill Main Road (B6054)

Greenhill Parkway (B6054)

Bradway Road

Finish: Turn round, stop just after Brad/Pros Road sensor

Distance: 1400 counts/28km

Time: 29-33 minutes

ROUTE 4

File reference: STx

Start: Sheffield/Barnsley boundary west end Stocksbridge

Manchester Road through Stocksbridge

A6102

Langsett Road North (A6102)

Low Road (Oughtibridge, A6102)

Langsett Road South (towards Stocksbridge)

Low Road

Langsett Road South (towards Sheffield, A6102)

Middlewood Road (A6102)

Catch Bar Lane

Park Side

Right onto Penistone Road, A61

Gibraltar Street (A61)

West Bar

Bridge Street

Blonk Street

Exchange Street

Once round Park Square roundabout

Duke Street (A616)

City Road (A616)

Birley Moor Road (A616)

Mosborough (A616)

Finish: Drive on left after Eckington sign

Distance: 1512 counts/30.2km

Time: 31-35 minutes

ROUTE 5

File reference: CBx

Start: Sheffield/Derbyshire boundary, A61

Chesterfield Road South (A61)

Meadow Head (A61)

Chesterfield Road (A61)

London Road (A61)

Queens Road (A61)

St Mary's Road

Matilda Street

Shoreham Street

Leadmill Road

Sheaf Street (A61)

Once round Park Square roundabout

Exchange Street

Castle Gate

Bridge Street

West Bar

Gibraltar Street (A61)

Infirmary Road (A61)

St Phillips Road (A61)

Penistone Road (A61)

Penistone Road North (A61)

Halifax Road (A61)

Continue on A61 to junction 36, M1

Join A6135 towards Chapeltown

Finish: Sheffield/Rotherham boundary A6135

Distance: 1440 counts/28.8km

Time: 31-35 minutes

ROUTE 6

File reference: RNGx

Start: Sheffield/Derbyshire boundary, Ringinglow Road

Ringinglow Road towards Sheffield

Knowle Lane

Ecclesall Road South (A625)

	Bear right into Psalter Lane
	Cemetery Road
	Summerfield Street
	Right onto Ecclesall Road (A625)
	Moore Street
	Charter Row
	Furnival Gate
	Arundel Gate
	Right at Castle Square
	High Street
	Commercial Street
	Once round Park Square roundabout
	Exit onto Sheffield Parkway (A57)
	Sheffield Parkway (A57/A630)
	Round roundabout junction 33, M1
	Parkway towards Sheffield
	Exit A57 towards Worksop
	Handsworth Road (A57)
	Retford Road (A57)
	Sheffield Road (A57)
	Round roundabout, back towards Sheffield
Finish:	Sheffield boundary

Distance: 1510 counts/30.2km

Time: 28-32 minutes

ROUTE 7

File reference: ABx

Start:	Sheffield/Derbyshire boundary A621	
	Baslow Road (A621)	
	Abbeydale Road South (A621)	
	Abbeydale Road (A621)	
	London Road	
	Left onto St Mary's Gate	
	Round roundabout	
	St Mary's Gate	
	St Mary's Road	
	Suffolk Lane	
	Fornham Street	
	Right onto Suffolk Road	
	Granville Square	
	Matilda Street	
	Shoreham Street	
	Leadmill Road	
	Sheaf Street (A61)	
	Once round Park Square roundabout	
	Exit Exchange Street	
	Furnival Street	
	Effingham Road (B6073)	Alternative route
	Lovetot Street	Foley Street
	Attercliffe Road (A6178)	Leveson Street
	Attercliffe Common (A6178)	Attercliffe Road
	Sheffield Road (A6178)	
	Left towards Meadowhall Shopping Centre	

Meadowhall ring-road

Left onto Meadow Hall Road towards City, A6109

Brightside Lane (A6109)

Savile Street East (A6109)

Left into Sutherland Street

Right onto Attercliffe Road

Across gap in central reservation

Savile Street

Left onto Attercliffe Road

Left into Sutherland Street

Finish: By Albert Pub on left

Distance: 1260 counts/25.2km

Time: 29-33 minutes

DERBYSHIRE ROUTE

File reference: DBxx

Start: Junction B6061/Winnats Pass

Winnats Pass

A625 east

Castleton

Hope

Turn round at road to Hope station

A625 west

Turn right into Edale

Edale road

Finish: Car park on right before Edale village

Distance: 710 counts/14.2km

Time: 20 minutes

SHEFFIELD COMBINED ROUTE

File reference: SCHx

Start:	15m west of Moscar Top sensor A57
	Manchester Road (A57)
	Turn into Rivelin Valley Road (A6101)
	Holme Lane
	Loxley New Road
	Holme Lane
	Left onto Middlewood Road (B6079)
	Leppings Lane
	Penistone Road towards city (A61)
	Shalesmoor (A61)
	Moorfields (A61)
	Gibraltar Street (A61)
	West Bar
	Bridge Street
	Lady's Bridge
	Blonk Street
	Exchange Street
	Twice round Park Square roundabout
	Exit Parkway (A57)
	Exit Prince of Wales Road (south, A6102)

	Ridgeway Road (A6102)
	Norton Avenue (A6102)
	Bochum Parkway (A6102)
	Left onto A61 (south)
	Round roundabout
	A61, north
	Greenhill Main (B6054)
	Greenhill Parkway (B6054)
	Bradway Road (B6054)
Finish:	Brad/Pros Road sensor

Distance: 1758 counts/35.2km

Time: 40 minutes

APPENDIX 2

DETAILS OF COMPAC 3 IRT AND BONDWELL 8 PORTABLE COMPUTER

Minolta/Land Cyclops Compac 3 Infra-red Thermometer

SPECIFICATION

Instrument type: Cyclops Compac 3.

Temperature range: -50 to 500°C.

Indication: 3-digit LCD display on back panel in 1° or 0.1° steps.

Measuring modes: Continuous measure; peak measure; monitor.

Optical system: 8° field of view with 1° and 1.7° measuring circles.

Target Diameter: 35mm at 2m.

Detector: Pyroelectric cell.

Spectral response: 8 to 14um.

Emissivity adjustment: 0.01 to 1.00 with 0.01 step graduations.

Response time: 0.5 seconds.

Operating temperature range: 0 to 50°C.

Uncertainty: +/-(1%K + 1 digit), in ambient temperature 20°C to 30°C, effective emissivity more than 0.99 and target at 2m greater than 48mm.

Repeatability: +/-(0.1%K + 1 digit).

Power source: 6xAA batteries, consumption 25mA (approx.).

Digital output: ASCII code, RS232C, 9600 bps.

Dimensions: 90(H) x 82(W) x 126mm(L).

Weight: 720g including batteries.

SOURCE: Land Infrared Ltd, Compac 3 IRT brochure.

Bondwell 8 Lapsize Portable Microcomputer

SPECIFICATION

CPU: 80C88; 4.77 Mhz system clock; operate in minimum mode.

Memory: 256 Kbyte standard user RAM.

Display: LCD display; view area, 224 x 70mm; standard IBM character set.

Disk drive: Built-in 3.5inch microfloppy disk drive; double sided, double density; 720 Kbyte formatted capacity.

Keyboard: 76 full-stroke keys.

Real time clock: time of day clock and calendar.

External interface: Serial port, standard RS232C interface; parallel port; second drive port; RGB video port; composite video port.

Operating system: MS-DOS version 2.11.

Software included: MS-DOS system and utilities; GW BASIC version 2.0.

General: Dimensions, 284(L) x 78(H) x 310(W)mm; net weight 5.5kg; power, built-in rechargeable battery with external AC to DC power adaptor.

SOURCE: Bondwell International Ltd, model 8 user's manual.

APPENDIX 3

CALIBRATION OF IRT AND OTHER MEASURING INSTRUMENTS

Determination of Emissivity of Melting Ice

Before carrying out the calibration and laboratory tests it was necessary to determine the emissivity of melting ice using the Compac 3 IRT. The method used is discussed in chapter 3 section 3.4.1. The emissivity value of melting ice was determined as 0.99 and this value was used in the calibration, laboratory and road tests with the Compac 3.

Calibration Prior to Laboratory Tests

The measuring instruments used during the laboratory tests (IRT, thermocouples and maximum-minimum thermometer) were calibrated against the BSI standard test thermometer (see photo 4.3) at room temperature (20-21^{o}C) and 0^{o}C (except maximum-minimum). These tests took place in the constant temperature room. The Compac 3 IRT had be checked and calibrated by the manufacturer (LAND) during summer 1989 and the calibration certificate is shown in photo A3.1.

ROOM TEMPERATURE

Photo A3.2 shows the method of calibration at room temperature. The IRT's cap was left on over the optical system creating a blackbody environment and the emissivity set at 1.00. The BSI test thermometer, with thermocouples (a, b and c)

attached to its bulb, and maximum-minimum thermometer were placed next to the IRT. No readings were made for a period of 100 minutes to ensure all temperatures were equal.

Five sets of readings were then taken at 30 minute intervals. A single reading was noted for the test thermometer, thermocouples and maximum-minimum. The average of ten readings was used for the IRT. The results are shown in table A3.1. NB. the maximum-minimum thermometer was readable to 0.5^{o}C while the IRT, thermocouples and test thermometer to 0.1^{o}C.

CALIBRATION AT 0^{o}C

Melting ice was used for calibrating at 0^{o}C (see photo A3.3). The BSI test thermometer (with thermocouples attached) was inserted into the ice, the IRT cap removed and emissivity adjusted to 0.99. The results are shown in table A3.2.

The calibration tests at room temperature and 0^{o}C confirmed that the IRT accurately measured temperatures when operating in a constant temperature environment and with the correct emissivity setting. There were small errors in readings made by the thermocouples and the laboratory test results were corrected accordingly.

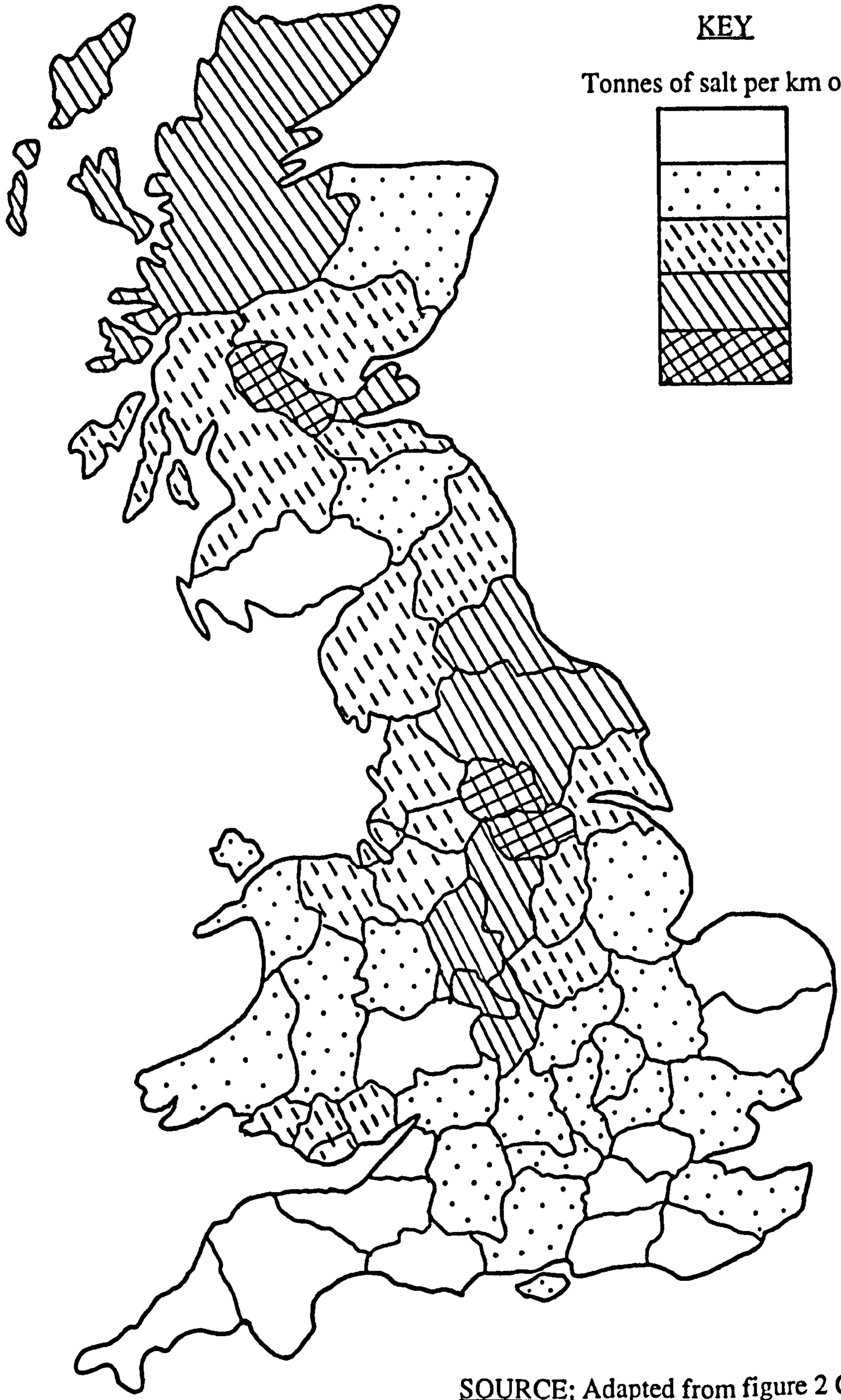
<u>Calibration Prior to Mapping</u>

Before each period of mapping the performance of the IRT was checked at 0^{o}C as shown above. In addition the whirling hydrometer used for measuring wet and dry bulb air temperatures was checked at 0^{o}C and found to be accurate to +/-0.2^{o}C. These checks were also carried out at the end of each mapping period to ensure the instruments were still performing well.

FIGURES, TABLES AND PHOTOS

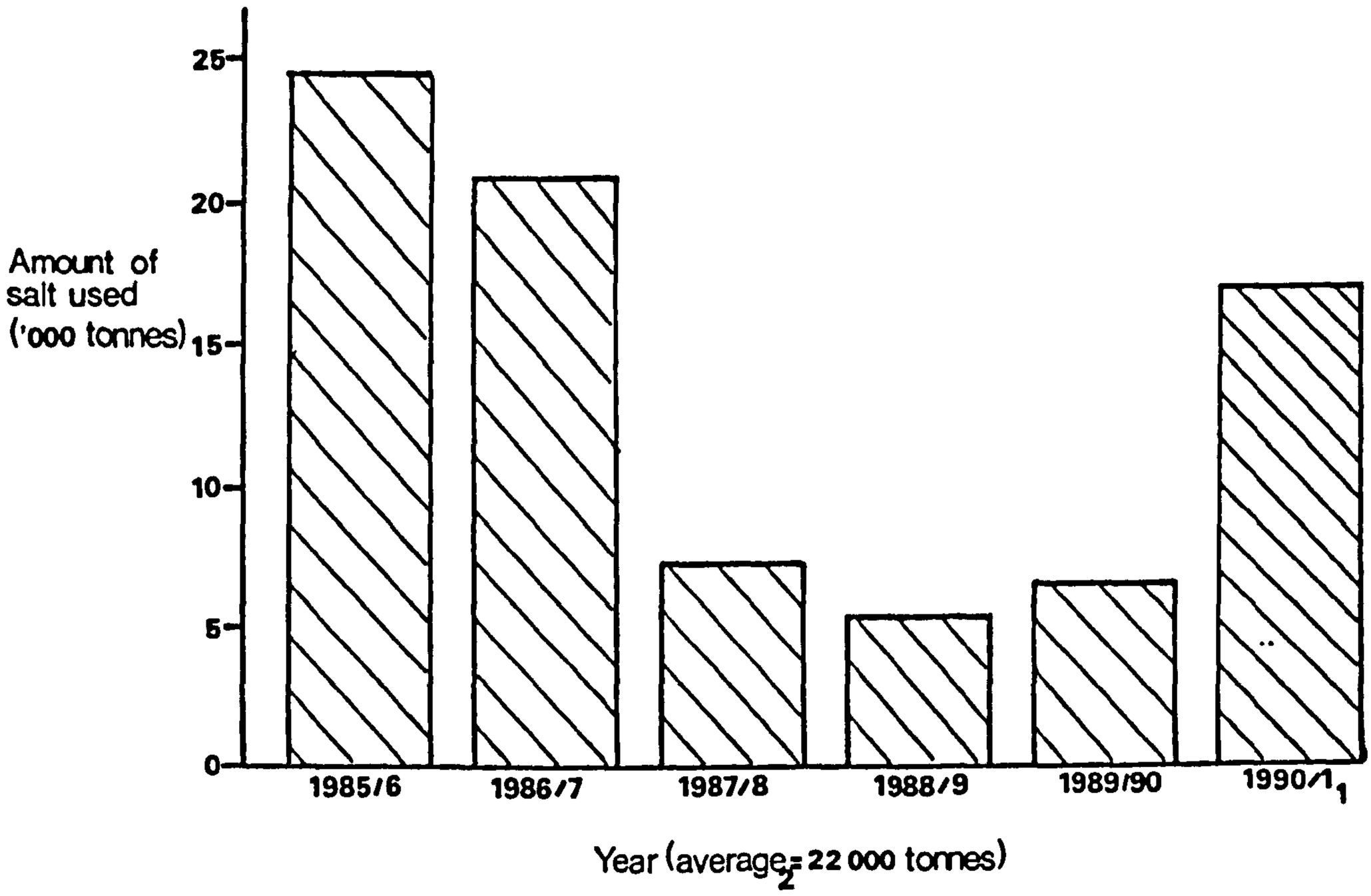
CHAPTER 1

Figure 1.1: Estimated Demand For Rock Salt By Counties/Regions Following A Winter Of Average Severity



SOURCE: Adapted from figure 2 County Surveyors'Society Report No.5/2 June 1985

Figure 1.2: Amount Of Salt Used In Sheffield 1985/86-1990/91

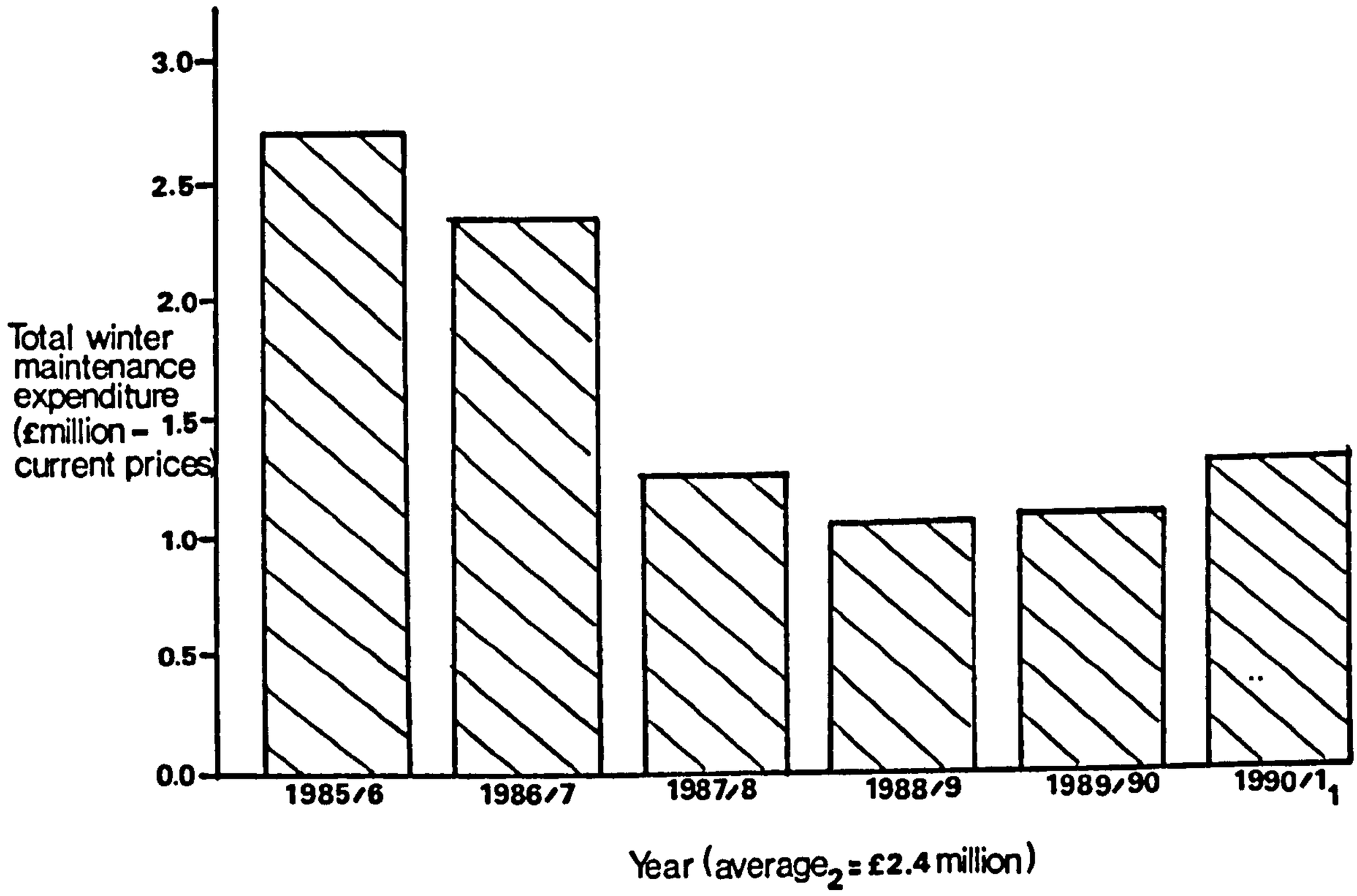


NOTES: 1) 1990/91 data to 12/2/91 - very little salt used after this date.

2) average salt usage is estimated.

SOURCE : Sheffield City Council Works Department.

Figure 1.3: Total Expenditure On Winter Maintenance In Sheffield 1985/86-1990/91

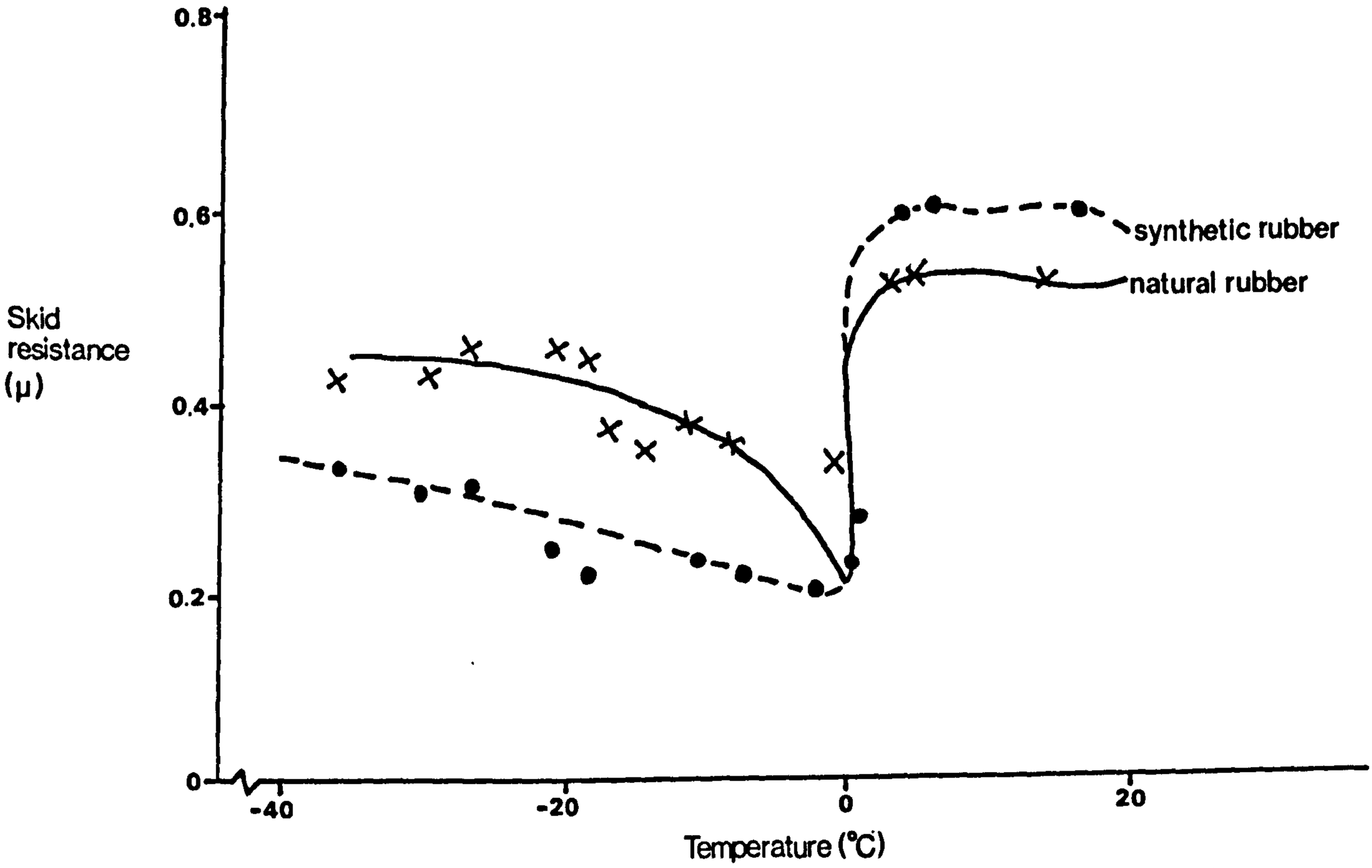


NOTES: 1) 1990/91 data to 12/2/91 - very little additional expenditure after this date.

2) average expenditure based on 1970/71-1989/90.

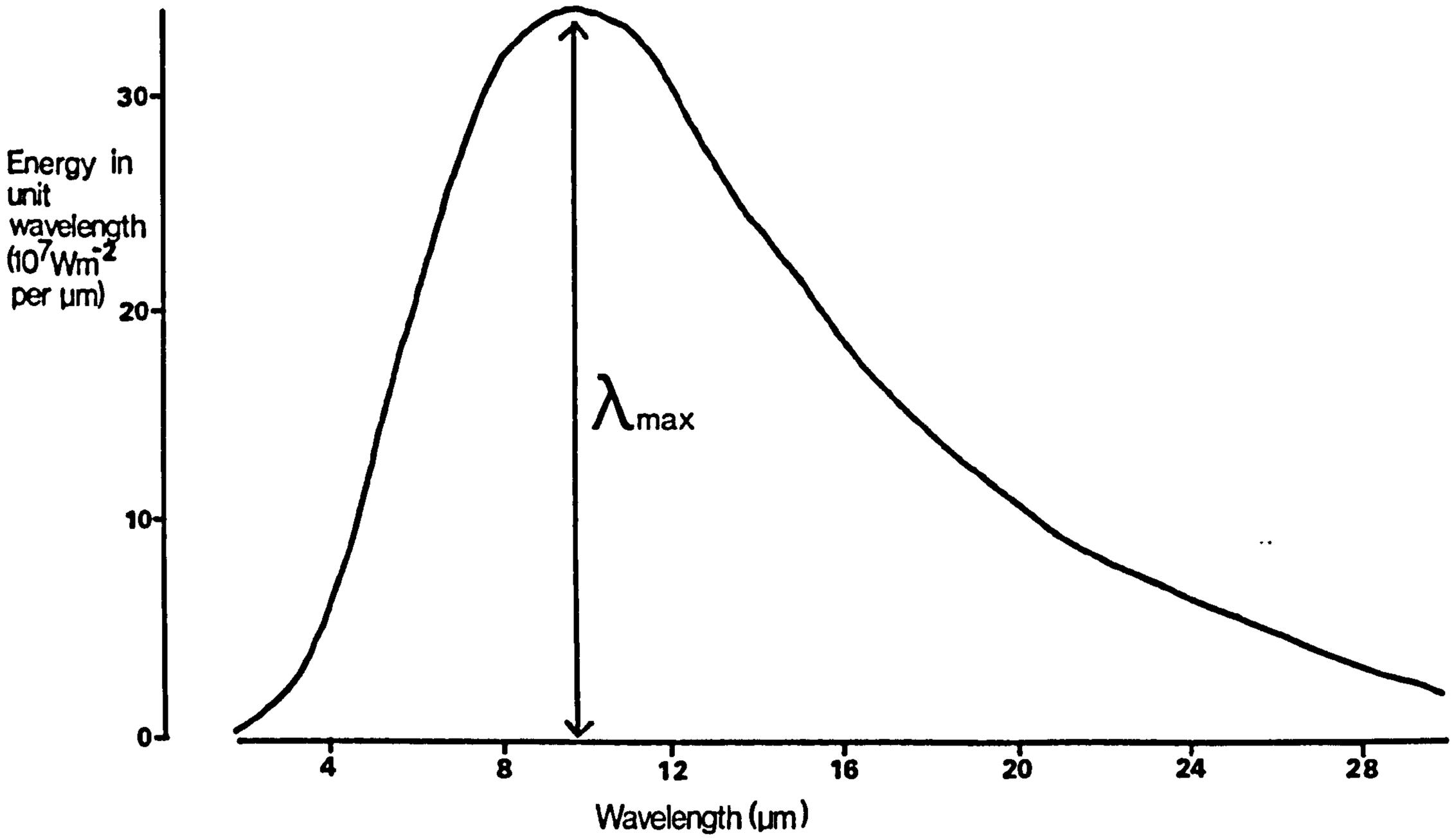
SOURCE: Sheffield City Council Works Department.

Figure 1.4: Skid Resistance As A Function Of Temperature



SOURCE: Moore, 1975

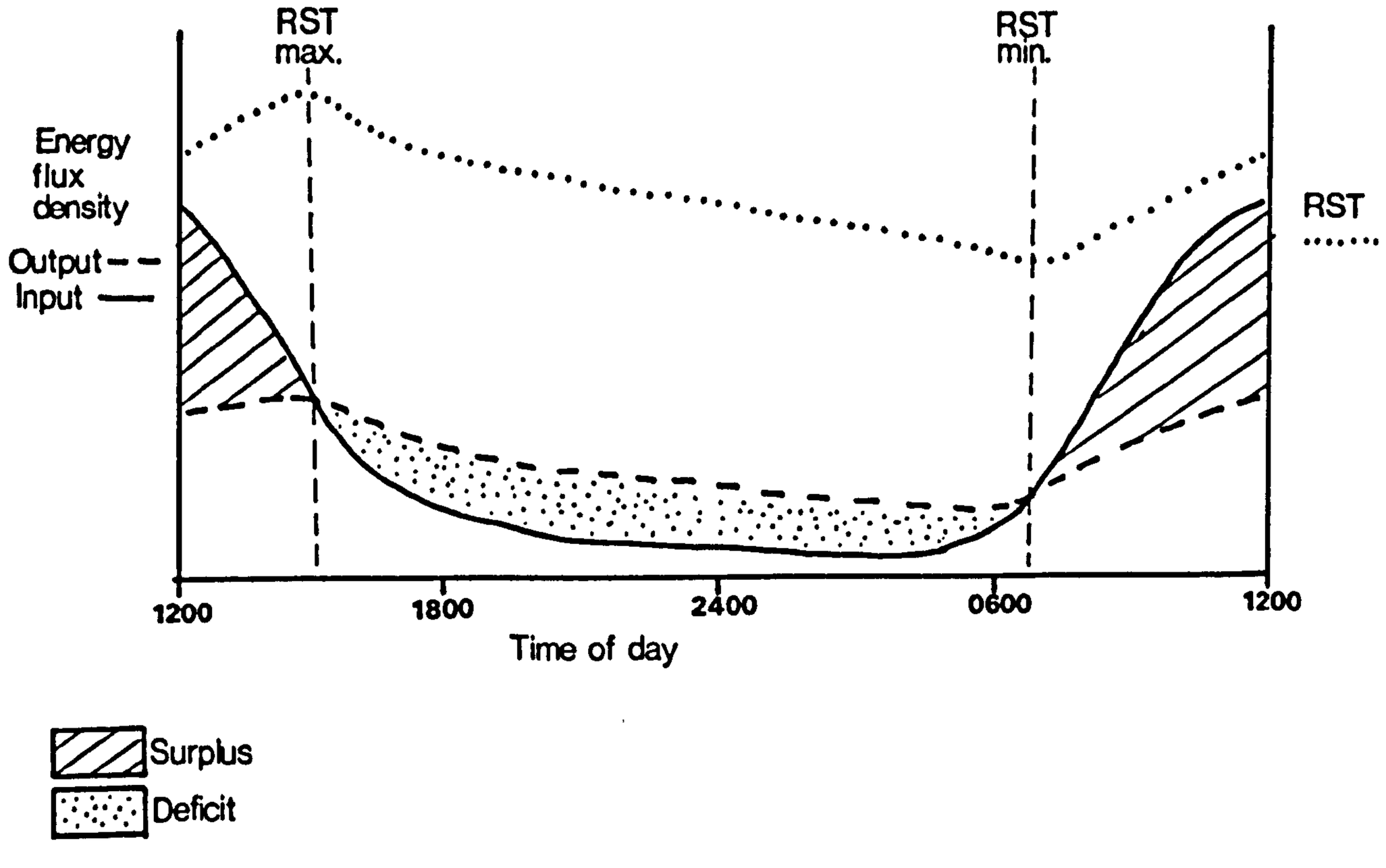
Figure 1.5: The Spectral Distribution Of Radiant Energy From A Full Radiator At A Temperature Of 300K - The Planck Curve



SOURCE: Monteith, 1973

Figure 1.6: The Relationship Between Surface Energy Exchange And The Diurnal Variation In RST

a) Night with clear skies and light winds:



b) Night with clear skies and light winds followed by increasing cloud and wind:

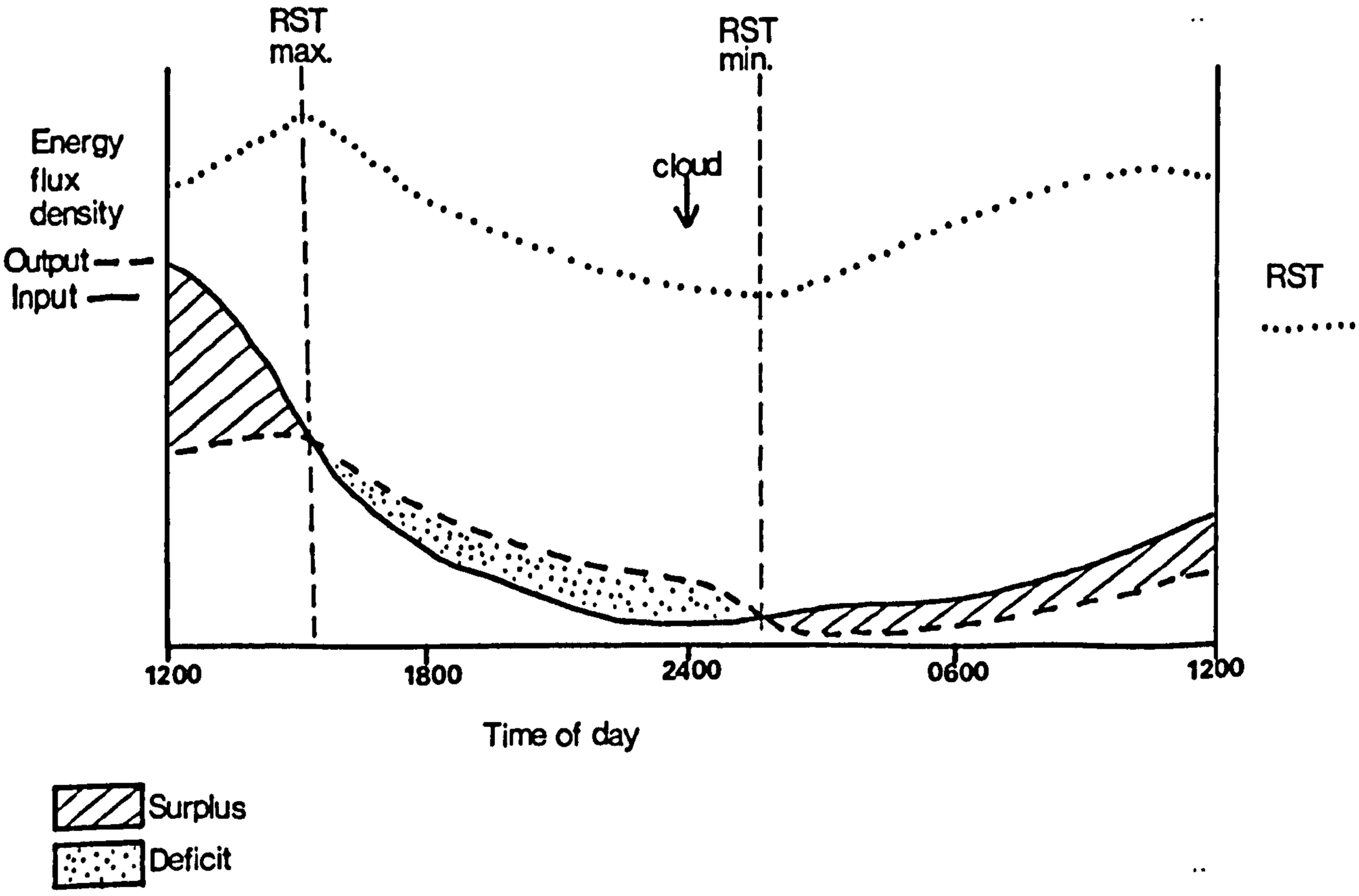
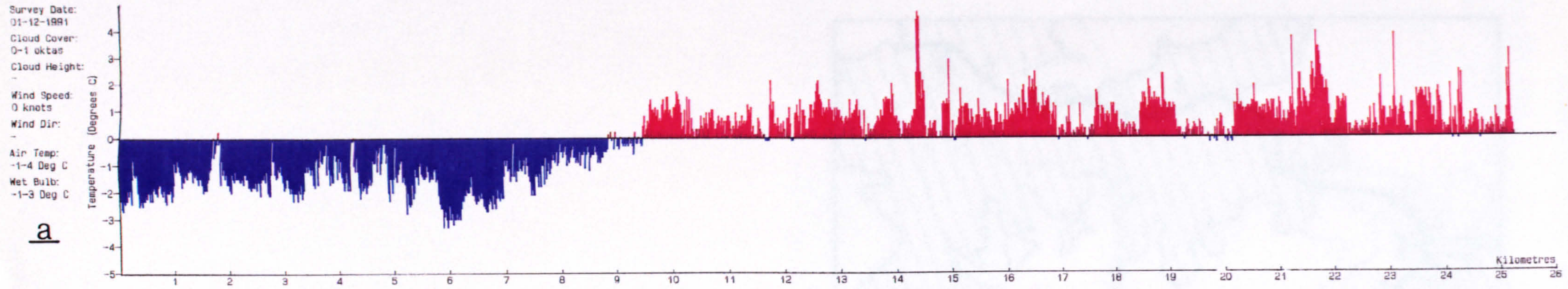
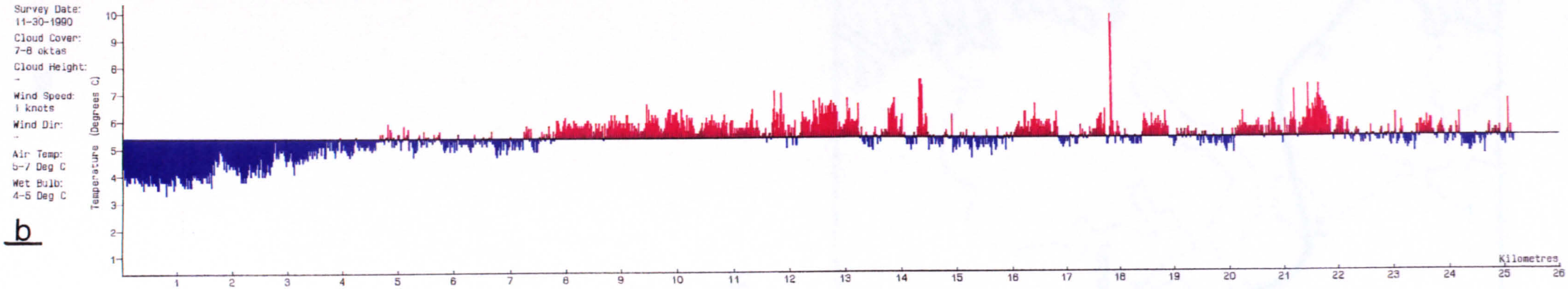


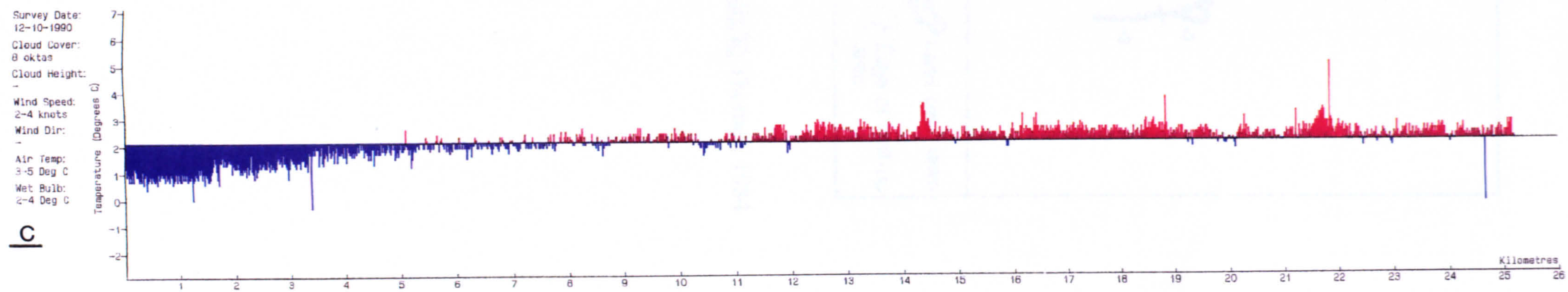
Figure 1.7: Examples of Extreme (a), Intermediate (b) and Damped (c) Thermal Fingerprints



a

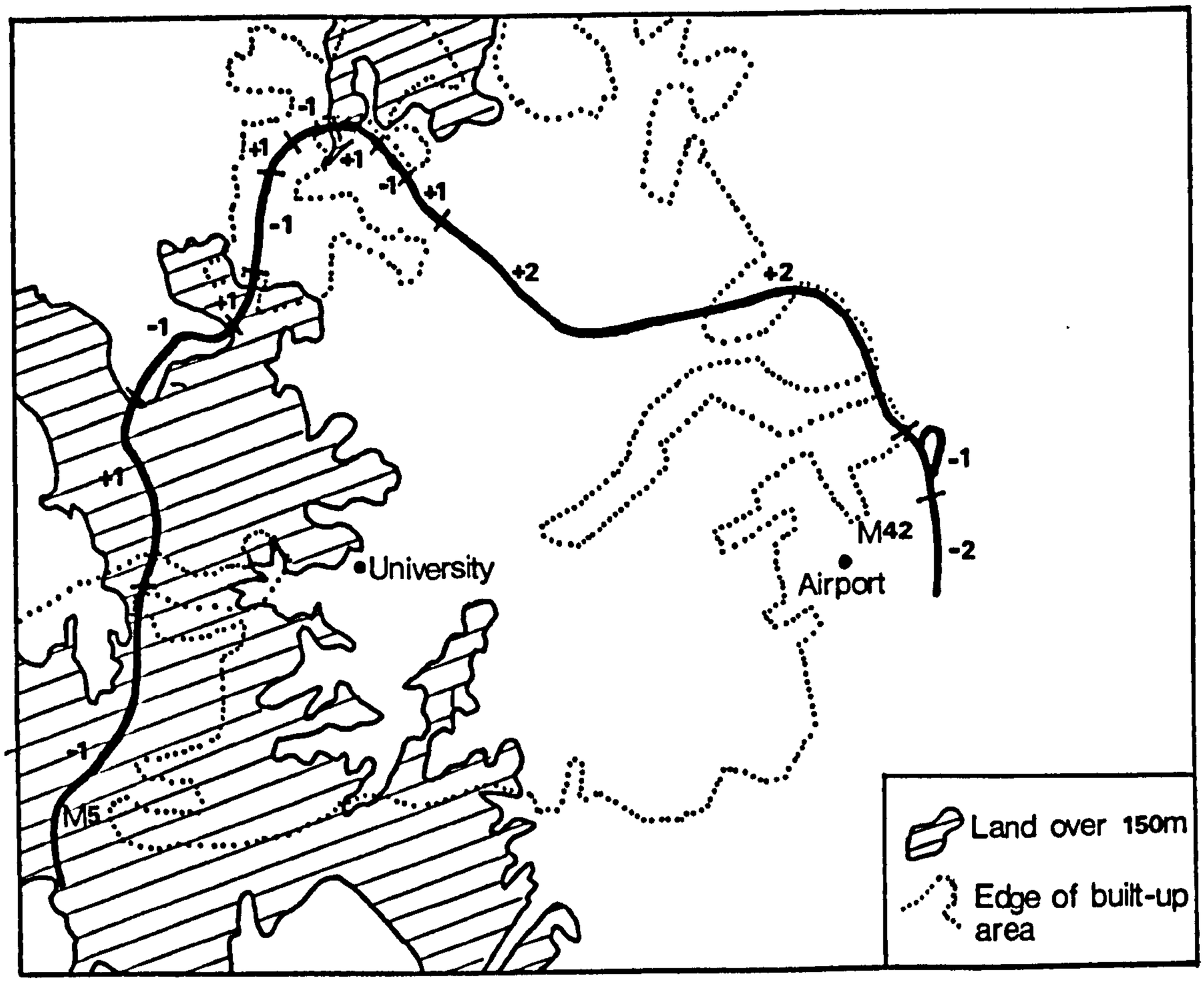


b



c

Figure 1.8: Thermal Map Of West Midlands Motorways



SOURCE: Thornes, 1984

Figure 1.9: Output From Icelert Computer: Table Of Sensor Data

06:25 14-02 1990

LOCATION MENU	SURFACE STATUSES	SURF. CONDS	SURFACE SENSOR TEMPERATURES °C			SURF. TREND ½ HR	AIR TEMP. °C	DEW POINT °C	R.H %	PRE	WS	WD	TIME
MOSSCART	SB	W	1.6			=	3.2						06:12
MOREHALL	NL	W	3.4			▲	5.0						05:33
ELLIOT L	NL	D	3.0			▼	3.8						05:34
TINSLEY	NL	W	5.0			=	6.6						05:35
FR WALES	NL	1	0.0			▼	5.0						05:37
BIRLEY M	NL	W	2.4			=	4.8						05:38
RINGLOW	NL	D	2.2			▼	4.6						05:40
BRADFROS	NL	3	2.6			▼	5.2						05:41
HILLFOOT	NL	3	2.6			=	6.4						05:43
WHISTON	NL	2	2.6			=	4.6						05:44
S ASTON	NL	D	3.4			▼	4.0						05:45
MALTBY	NL	1	2.8			▼	4.6						05:46
STUBBIN	NL	D	2.6			▼	4.4						05:47
DODWORTH	SB	D	0.2			▲	1.4						07:52
SCOUT	NL	1	2.2			▼	3.8				27	N	05:50
BORDHILL	NL	3	2.0			▲	2.8						05:51

TABLE	24 HR SURFACE	1 HR SURFACE	24 HR AIR	1 HR AIR
RAIN / WIND	FORECAST	FORECAST TEXT	2-5 DAY FCT.	24 HOUR FCT.
MORNING SUM.	RADAR IMAGES	DISP. MENU 2	FILE MENU	COMMS MENU

Figure 1.10: Output From Icelert Computer: Plot Of 24-Hour RSTs

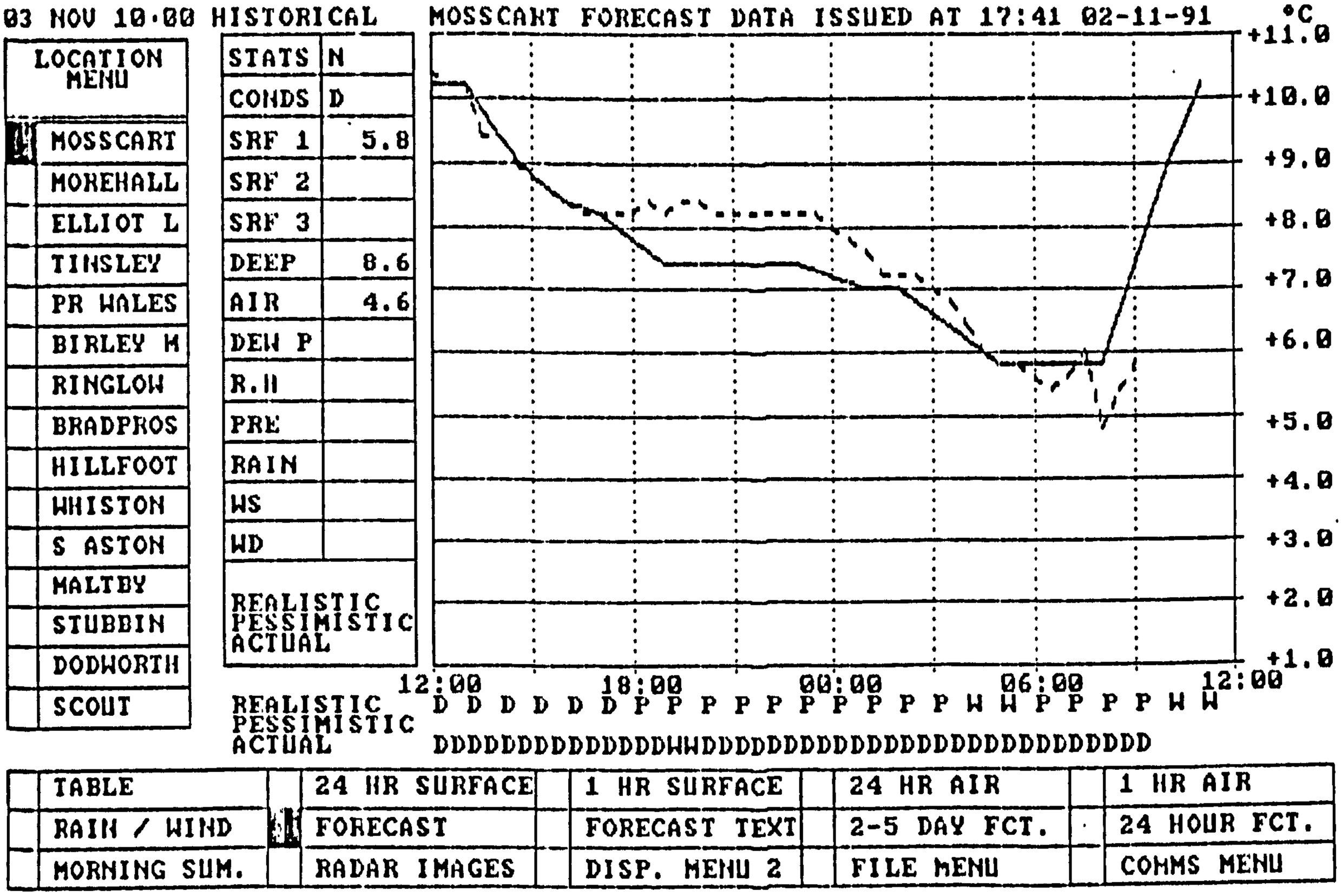


Figure 1.11: Output From Icelert Computer: Forecast
Text Issued By Leeds Weather Centre

18:53 28-03-1992
THE 2-5 DAY OUTLOOK ISSUED AT 1015Hr, Saturday 28th March 1992.

TOMORROW AFTERNOON AND NIGHT: MOSTLY CLOUDY, WITH OUTBREAKS OF RAIN.

MONDAY: MOSTLY CLOUDY, WITH RAIN AT TIMES. COLD EASTERLY WINDS.

MONDAY NIGHT: CLEAR PERIODS. SCATTERED SHOWERS WITH SLEET AND POSSIBLY SNOW ON THE HILLS. FRESH NORTHEAST WINDS.

TUESDAY: SUNNY INTERVALS AND WINTRY SHOWERS. COLD NORTHEAST WINDS.

TUESDAY NIGHT: CLEAR PERIODS AND A FEW SHOWERS OF SLEET OR POSSIBLY SNOW. RSTs COMING CLOSE TO ZERO.

FORECASTER: E. Hall LEEDS WEATHER CENTRE (0532) 449544

	TABLE		24 HR SURFACE		1 HR SURFACE		24 HR AIR		1 HR AIR
	RAIN / WIND		FORECAST		FORECAST TEXT		2-5 DAY FCT.		24 HOUR FCT.
	MORNING SUM.		RADAR IMAGES		DISP. MENU 2		FILE MENU		COMMS MENU

Table 1.1: Some Indicators Of The Severity Of A Sheffield Winter

SEVERITY INDICATOR	WINTER								AVERAGE[2]
	1962/63	1978/79	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91[1]	
DAYS OF SNOW FALLING[3]	14	30	12	9	4	3	6	12	10
DAYS OF SNOW LYING[3]	70	71	41	18	9	7	6	14	23
TOTAL DEPTH OF SNOW[4]	438	1600	580	470	240	150	120	940	400
FREQUENCY OF RST <= $0^{O}C$[5]	84	71	67	44	22	20	14	37	60
NIGHTS SALTING	N/A	N/A	94	61	46	45	42	55	66

NOTES: 1) 1990/91 data to 12.2.91 - little change in these figures after that date.

2) average based on period 1970/71-1989/90 except salting, 1979/80-1989/90.

3) Data from Weston Park.

4) Data from Weston Park - 1962/63, amount lying at time of measurement, else total fallen (mm)

5) Estimated using data on air minimum (Weston Park) and Leeds Met Office predictions.

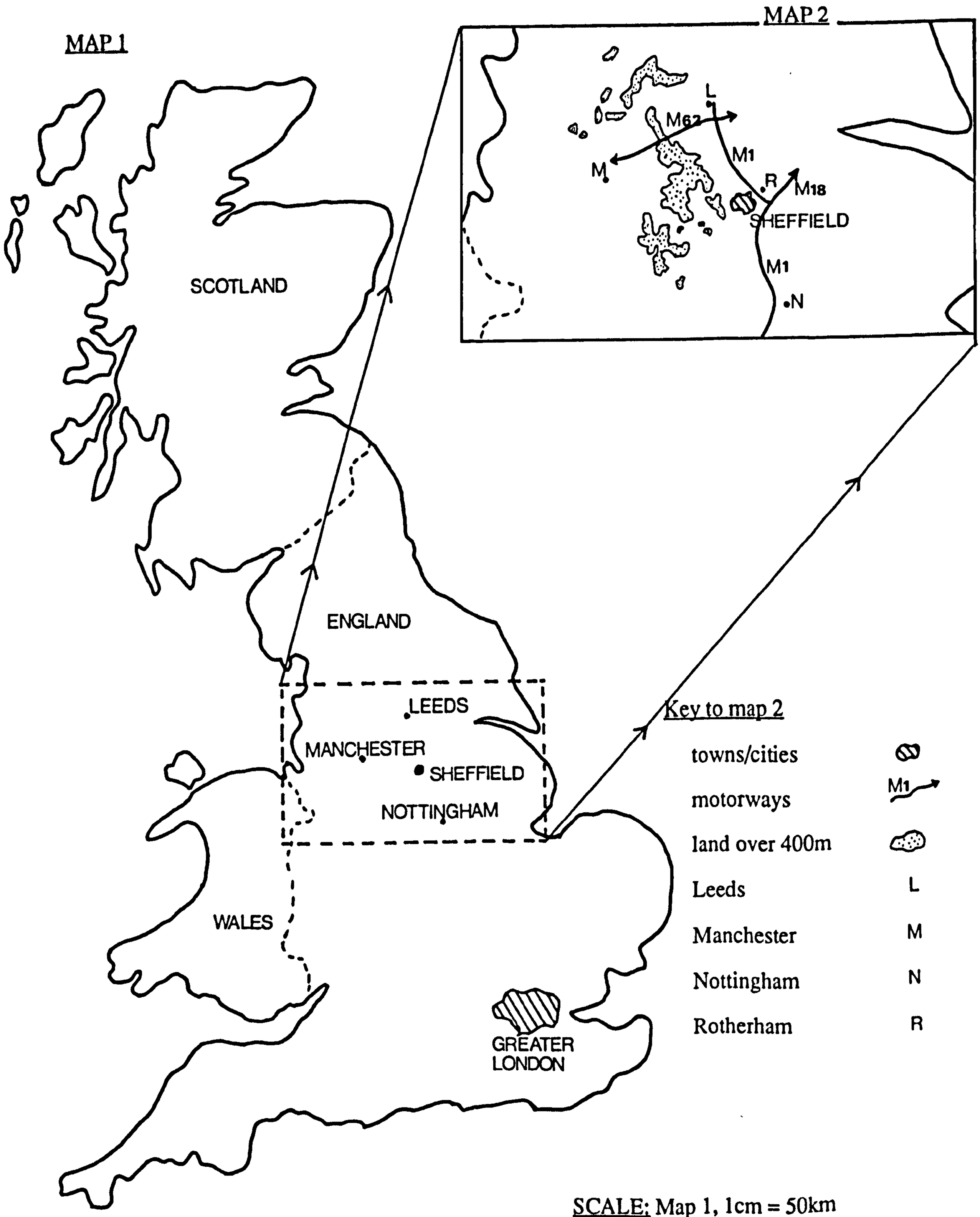
SOURCE: Sheffield City Council Works Department.

Photo 1.1: Icelert Sensor At Moscar Top

Photo 1.2: Icelert Sensor Heads Embedded In Road Surface

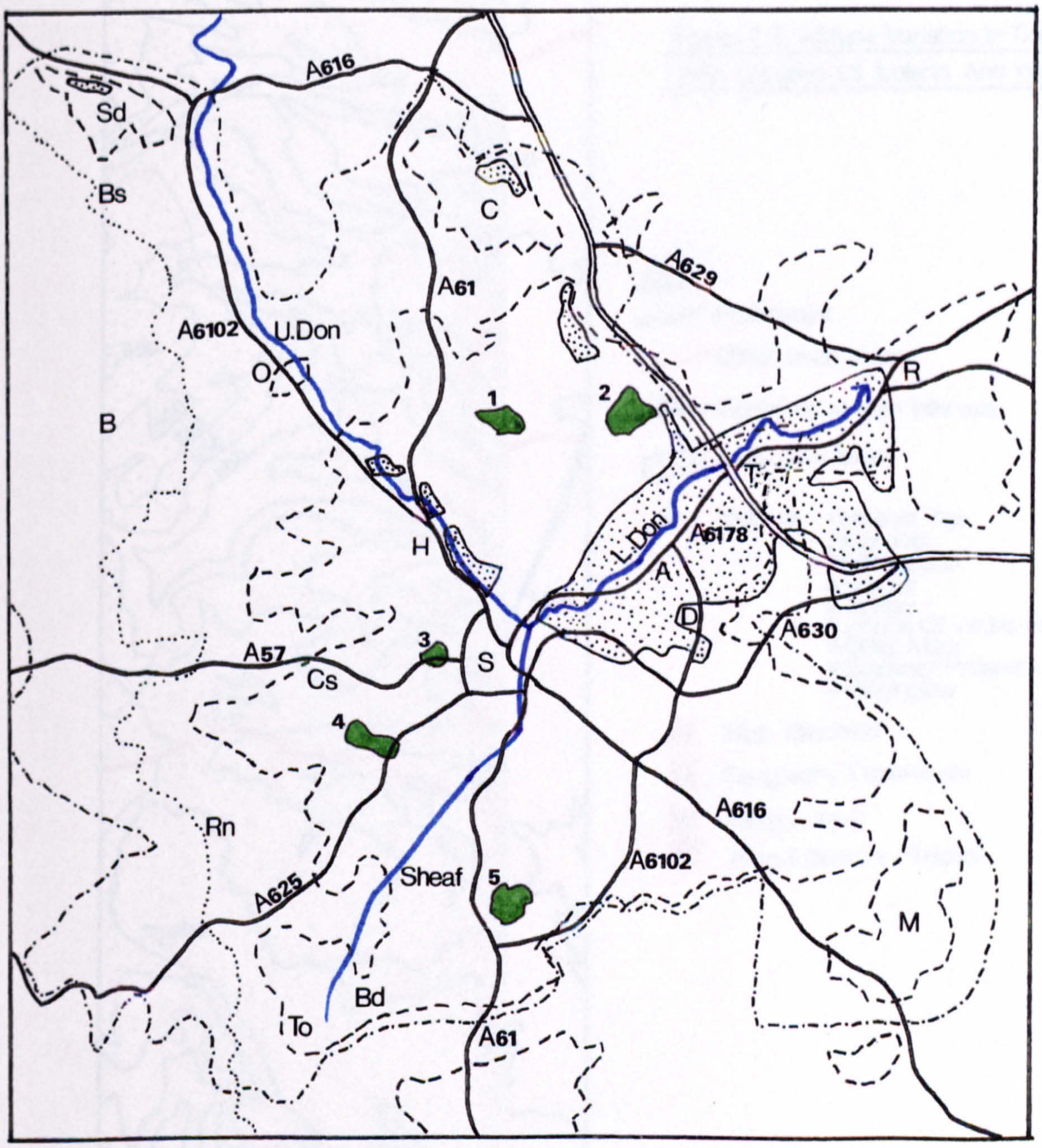
CHAPTER 2

Figure 2.1: The Location Of Sheffield



SCALE: Map 1, 1cm = 50km
Map 2, 1cm = 25 km

Figure 2.2: Sheffield Land-Use And Main Road Network



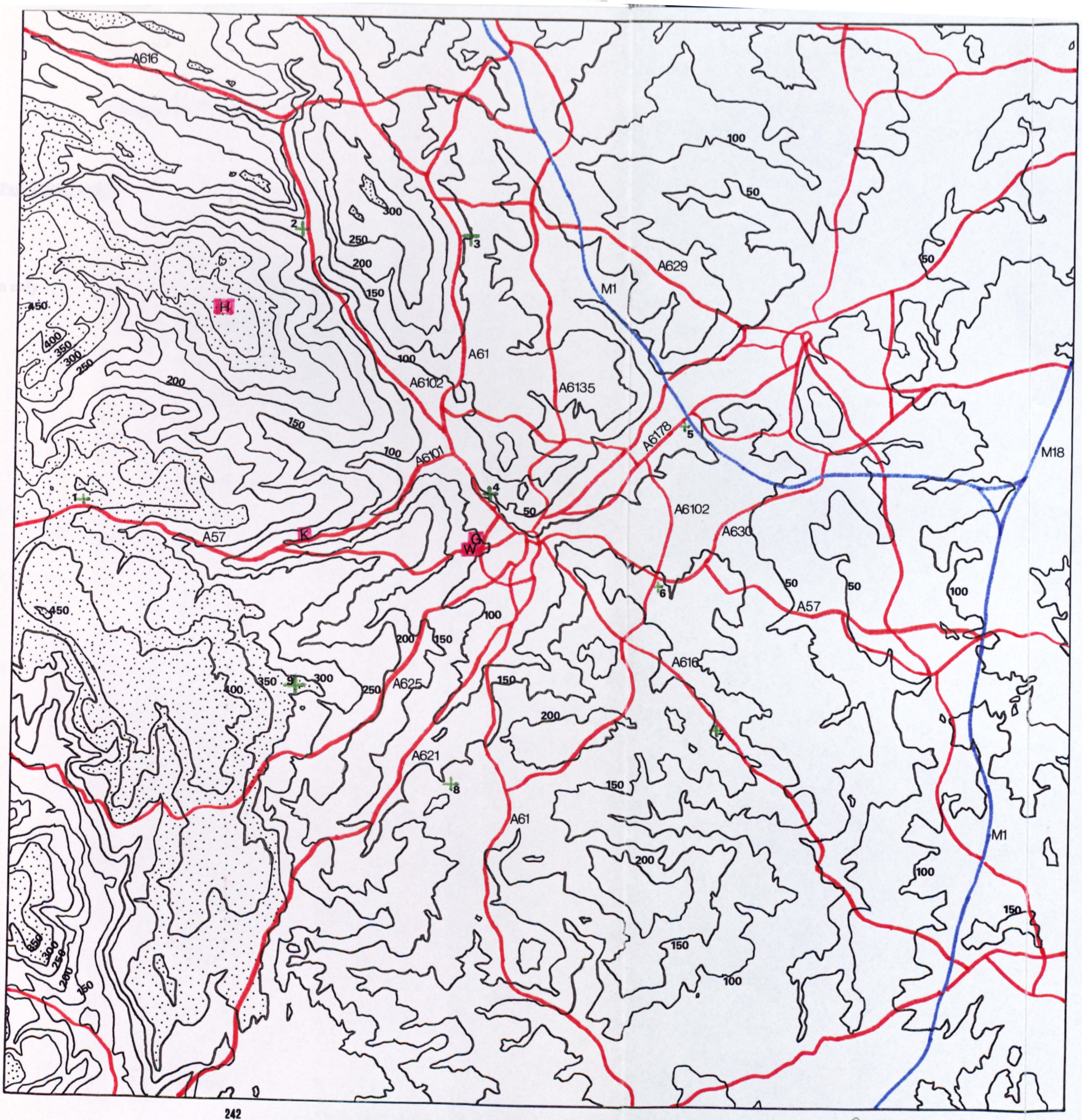
SCALE: 7.5mm = 1km

Key

- City of Sheffield boundary
- motorways
- other major roads
- Peak District National Park boundary
- built-up areas
- S Sheffield city centre
- R Rotherham city centre
- main parks: 1) Parson Cross, 2) Concord, 3) Weston, 4) Endcliffe, 5) Graves
- main rivers
- main manufacturing (past and present)

- A Attercliffe
- B Bradfield
- Bd Bradway
- Bs Bolsterstone
- C Chapeltown/High Green
- Cs Crosspool
- D Darnall
- H Hillsborough
- M Mosborough
- O Oughtibridge
- Rn Ringinglow
- Sd Stocksbridge/Deepcar
- T Tinsley
- To Totley

Figure 2.3: Altitude Variation In The Sheffield Area
With Location Of Icelerts And Weather Stations



KEY

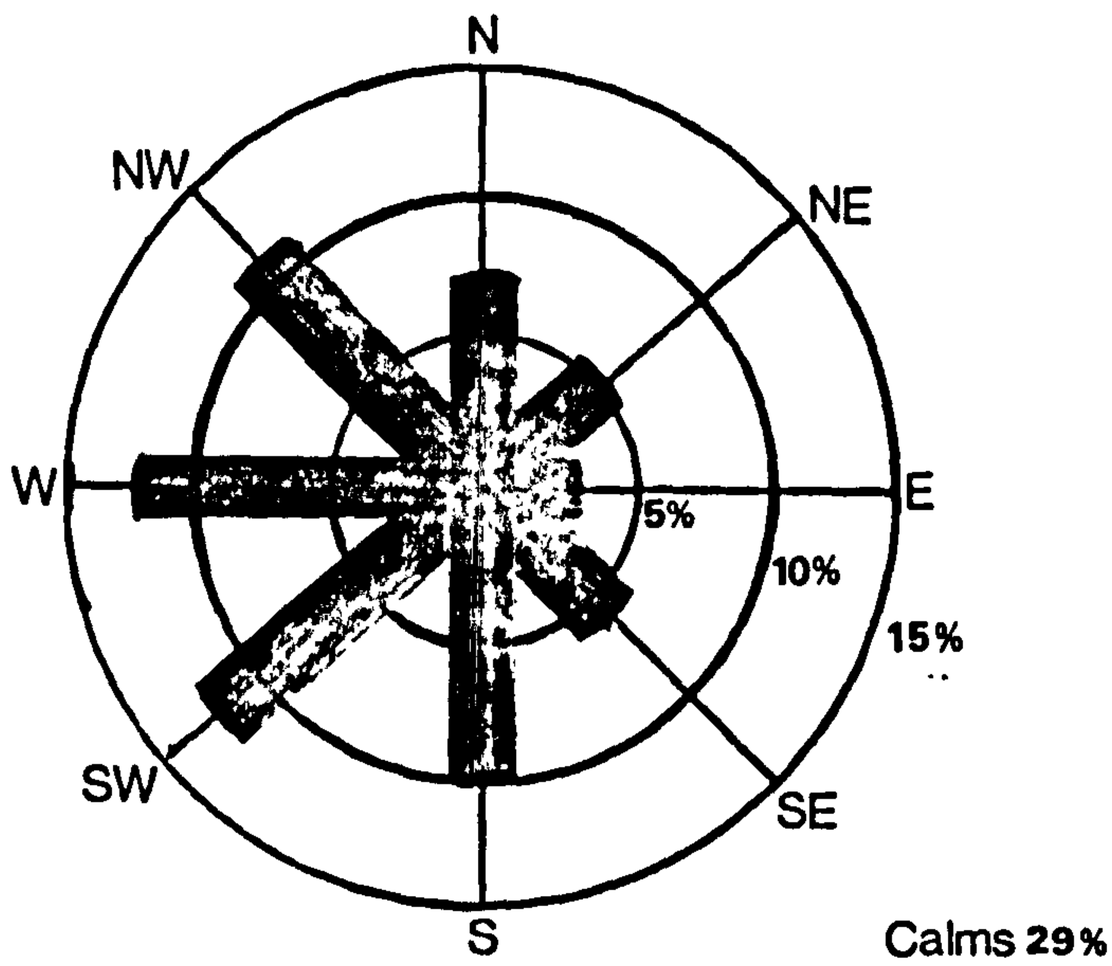
- Motorways
- Other main roads
- 200 Contours at 50m intervals
- Land over 300m
- Icelerts : 1 Moscar Top
  2 Morehall
  3 Elliott Lane
  4 Hillfoot
  5 Tinsley
  6 Prince Of Wales Road
  7 Birley Moor
  8 Bradway/Prospect Road
  9 Ringinglow
- H High Bradfield
- G Geography Department
- W Weston Park
- K King Edward's Hospital

SCALE 10mm= 1km

Figure 2.4: Sheffield Wind Rose

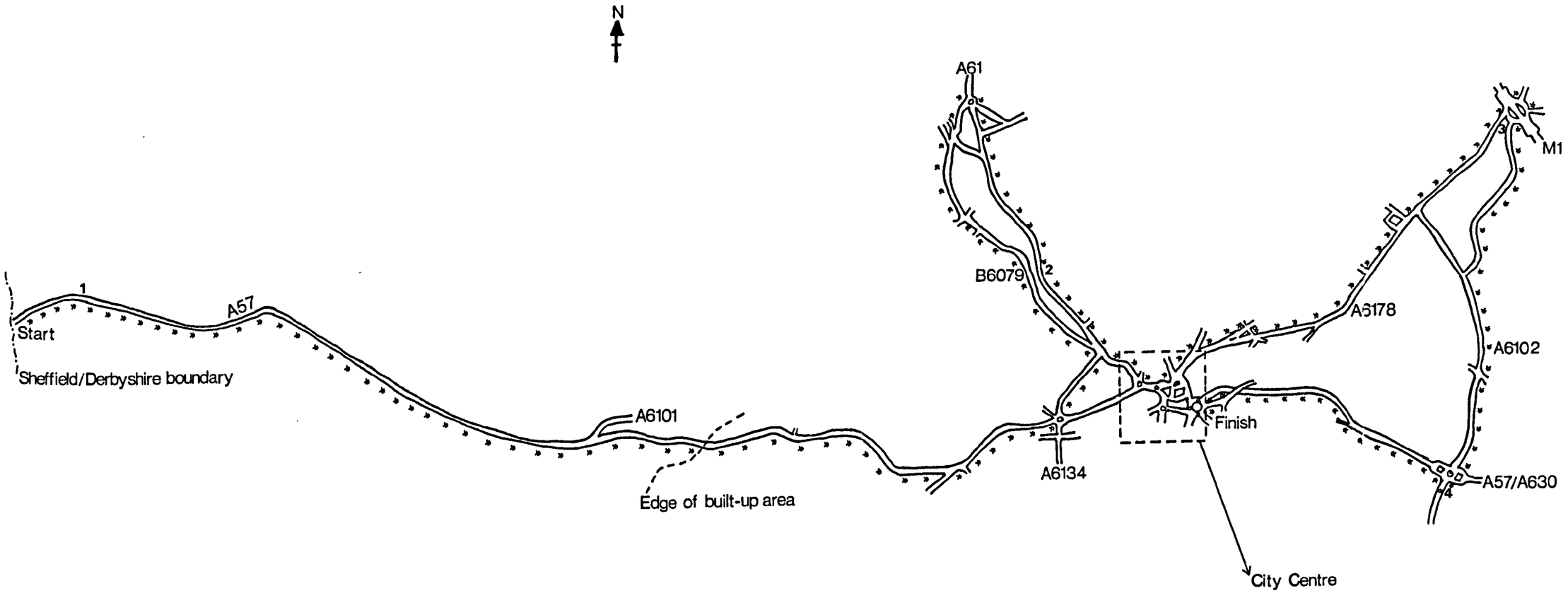
Weston Park (1951-1980)

Direction only



SOURCE: Sheffield City Museums, Information Sheet 15: The Climate Of Sheffield

Fig 2.5: Details of Route 1



SCALE: 2cm = 1km

KEY

- Route 1
- 1 Moscar Top
- 2 Icelerts Hillfoot
- 3 Icelerts Tinsley
- 4 Prince of Wales Road

Table 2.1 :The Climate Of Sheffield (1951-1980)

MONTH	SUN (hours)	RAINFALL (mm)	MAX. AIR TEMP.(^{O}C)	MIN. AIR TEMP.(^{O}C)	AV. MAX./ MIN.(^{O}C)	FROST (MIN.<= 0^{O}C)	DAYS SNOW LYING[1]
JANUARY	42	78	5.8	1.4	3.6	9.5	6.2
FEBRUARY	51	67	6.0	1.2	3.6	9.5	7.9
MARCH	95	64	8.5	2.4	5.5	4.3	3.1
APRIL	120	52	11.7	4.4	8.0	2.2	0.3
MAY	166	63	15.4	7.7	11.6	0.1	0.03
JUNE	182	56	18.6	10.1	14.4	0	0
JULY	160	63	19.8	12.1	15.9	0	0
AUGUST	148	72	19.6	11.8	15.7	0	0
SEPTEMBER	119	63	17.2	10.1	13.7	0	0
OCTOBER	88	64	13.7	7.3	10.5	0.3	0.3
NOVEMBER	52	84	8.9	4.1	6.5	3.4	3.4
DECEMBER	32	82	7.0	2.5	4.8	6.0	6.0

YEAR:

Mean daily maximum temperature (^{O}C)	12.7
Mean daily minimum temperature (^{O}C)	6.3
Mean daily maximum and minimum (^{O}C)	9.5
Mean annual rainfall (mm)	808
Mean annual sunshine (hours)	1258
Mean number raindays	183.5
Mean number of days with snow lying	20.0
Mean annual occurrence of frost (minimum <= 0^{O}C)[2]	35.2

NOTES: 1) at 0900 GMT

2) 1971-1990

SOURCE: Shefffeld City Museums, Information Sheet 15: The Climate Of Sheffield

Table 2.2: Lamb Weather Types For `Winters' 1988/89, 1989/90 and 1990/91

DATE	WINTER																	
	1988/89						1989/90						1990/91					
	MONTH																	
	Nov	Dec	Jan	Feb	Mar	Apr	Nov	Dec	Jan	Feb	Mar	Apr	Nov	Dec	Jan	Feb	Mar	Apr
1	A	E	A	ASW	U	SE	SW	A	S	C	CNW	U	NW	A	W	SE	A	W
2	A	E	A	ASW	CSE	CSE	SW	A	S	C	ANW	C	N	A	W	SE	S	W
3	AS	C	S	SW	C	E	W	A	S	W	AW	N	N	ANW	W	SE	S	W
4	ASE	C	W	W	SW	E	CW	A	S	S	W	A	N	AN	W	E	SE	C
5	A	NW	CW	W	S	E	CNW	A	S	S	W	AW	ANE	A	C	E	S	C
6	A	ANW	C	W	S	C	W	A	SW	C	W	A	A	A	W	E	E	SW
7	SE	AW	W	W	AW	C	W	A	W	C	W	AE	A	C	C	E	E	W
8	SE	AW	W	ASW	SW	U	C	ANE	W	W	W	A	ASE	C	C	E	CE	W
9	S	W	W	S	SW	S	W	A	W	W	W	A	SE	U	SW	E	C	SW
10	SW	AW	AW	AW	SW	C	CSW	A	W	SW	SW	W	C	A	SW	N	C	S
11	ASW	AW	SW	AW	ASW	C	CS	A	SW	C	AW	W	U	N	C	U	S	S
12	AW	A	W	W	U	C	A	U	W	CW	A	CW	S	N	U	CN	S	C
13	A	A	SW	W	C	C	A	C	W	W	S	C	CS	A	A	A	S	ANE
14	A	A	W	W	C	CN	A	C	W	W	ASW	W	CW	A	ASE	NW	SW	A
15	A	A	W	W	C	U	ASE	C	W	U	SW	W	W	A	SE	C	S	AE
16	AS	A	W	A	CNE	E	SE	SE	W	U	ASW	W	W	A	SE	N	C	NE
17	C	A	A	SW	A	N	SE	C	W	SW	S	W	W	ASE	S	U	C	AN
18	AN	W	A	SW	W	AN	SE	C	W	SW	S	W	W	A	S	A	SW	N
19	N	W	ASW	W	W	ANE	E	U	SW	SW	SW	C	W	ANW	SW	A	W	N
20	N	W	CSW	W	W	NE	E	SE	SW	SW	SW	E	C	C	AW	SW	C	ANW
21	A	W	CW	A	W	NE	E	C	SW	ASW	W	E	N	W	A	C	NW	NW
22	A	W	AW	W	W	N	NE	W	SW	S	W	A	A	W	A	C	N	U
23	A	W	SW	W	W	N	A	W	W	SW	W	A	W	SW	A	SW	N	ASW
24	A	W	S	C	W	N	ANE	S	W	C	NW	A	C	SW	A	W	A	S
25	A	SW	S	C	SW	N	A	SW	C	SW	A	A	CE	W	A	A	A	C
26	A	W	SW	C	S	C	A	A	W	C	A	AW	NE	CW	A	S	AE	A
27	A	W	S	NW	C	C	A	A	C	W	U	A	A	W	A	S	A	ASE
28	W	ASW	AW	CN	A	C	A	A	C	C	A	A	A	W	AS	A	A	AE
29	U	ASW	AW	–	A	U	A	SE	S	–	A	A	A	W	C	–	A	C
30	C	ASW	AW	–	AW	SW	A	SE	S	–	A	A	A	W	U	–	A	C
31	–	A		–	A	–	–	SE	SW	–	A	–	–	CW	U	–	AW	–

KEY

A	anticylonic	W	westerly
ANE	anticyclonic north-easterly	NW	north-westerly
AE	anticyclonic easterly	N	northerly
ASE	anticyclonic south-easterly	C	cyclonic
AS	anticyclonic southerly	CNE	cyclonic north-easterly
ASW	anticyclonic south-westerly	CE	cyclonic easterly
AW	anticyclonic westerly	CSE	cyclonic south-easterly
ANW	anticyclonic north-westerly	CS	cyclonic southerly
AN	anticyclonic northerly	CSW	cyclonic south-westerly
NE	north-easterly	CW	cyclonic westerly
E	easterly	CNW	cyclonic north-westerly
SE	south-easterly	CN	cyclonic northerly
S	southerly	U	unclassified
SW	south-westerly		

Table 2.3: Weather Data For Sheffield (Weston Park) For `Winters' 1988/89, 1989/90 And 1990/91

	WINTER																	
	1988/89						1989/90						1990/91					
	MONTH																	
	Nov	Dec	Jan	Feb	Mar	Apr	Nov	Dec	Jan	Feb	Mar	Apr	Nov	Dec	Jan	Feb	Mar	Apr
MEAN DAILY MAX. (°C)	9.0	9.8	9.0	9.1	10.9	9.6	9.0	6.7	8.9	9.7	12.4	13.1	8.8	6.7	5.5	4.8	10.7	11.4
MAXIMUM (°C)	14.6	13.1	12.0	13.9	17.2	16.5	13.7	11.9	13.1	17.5	19.8	23.2	15.6	11.8	12.6	12.7	18.3	19.7
MEAN DAILY MIN. (°C)	2.5	5.4	3.8	2.9	3.6	2.7	4.0	2.8	3.9	4.4	5.3	3.9	5.1	2.5	0.1	0.2	5.2	4.5
MINIMUM (°C)	-2.3	1.9	-1.2	-2.2	-1.8	-1.1	-2.0	-1.0	0.0	-0.7	-1.3	-1.8	0.8	-1.6	-4.2	-6.3	-0.3	-1.3
MEAN DAILY MAX. + MIN. (°C)	5.7	7.6	6.4	6.0	7.3	6.2	6.5	4.7	6.4	7.1	8.9	8.5	7.0	4.6	2.8	2.5	8.0	8.0
FROST (FREQ. MIN <= 0°C)	10	0	2	3	2 [1]	4	3	4	1	1	3	3	0	4 [2]	15	14 [3]	1	2 [4]
SUN (HOURS)	50.5	32.7	54.3	93.1	126.6	107.8	45.3	12.9	46.4	58.5	137.6	201.6	32.3	24.3	53.3	45.1	61.0	129.3
RAINFALL (mm)	68.6	36.0	20.6	75.3	77.7	15.5	42.6	159.1	128.7	115.2	21.6	25.9	47.9	133.1	86.8	68.5	58.7	67.2
RAINDAYS	11	12	11	17	19	21	13	16	25	20	11	11	16	20	17	16	20	12
SNOW LYING (DAYS)	4	0	0	1	0	2	0	2	2	2	0	0	0	3	2	15	0	0

NOTES: 1) 3 days missing
2) 6 days missing
3) 2 days missing
4) 1 day missing

See table 2.1 for average (1951-1980) figures.

Photo 2.1: Weston Park Weather Station

Photo 2.2: Open Moorland At Moscar Top

Photo 2.3: Tree-Lined Suburbs - Crosspool

Photo 2.4: Dense Terraced Housing - Hillsborough

Photo 2.5: Light Industry Along The Upper Don Valley (A61)

Photo 2.6: Sheffield's City Centre

Photo 2.7: Heavy Industry - Shepcote Lane

Photo 2.8: Sheffield Parkway (A57/A630) - Some Light Industry

CHAPTER 3

Figure 3.1: Vascar Pulse Unit

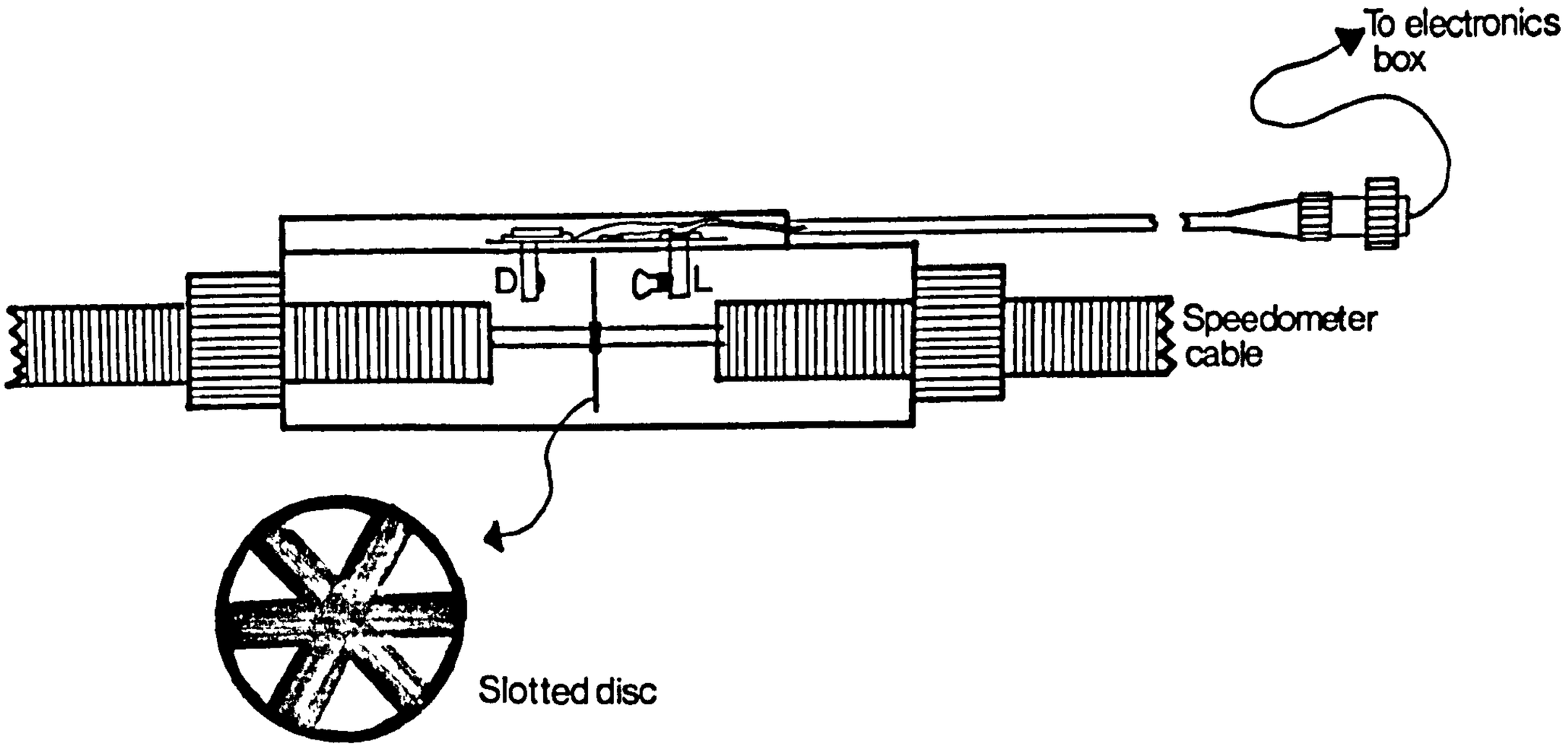
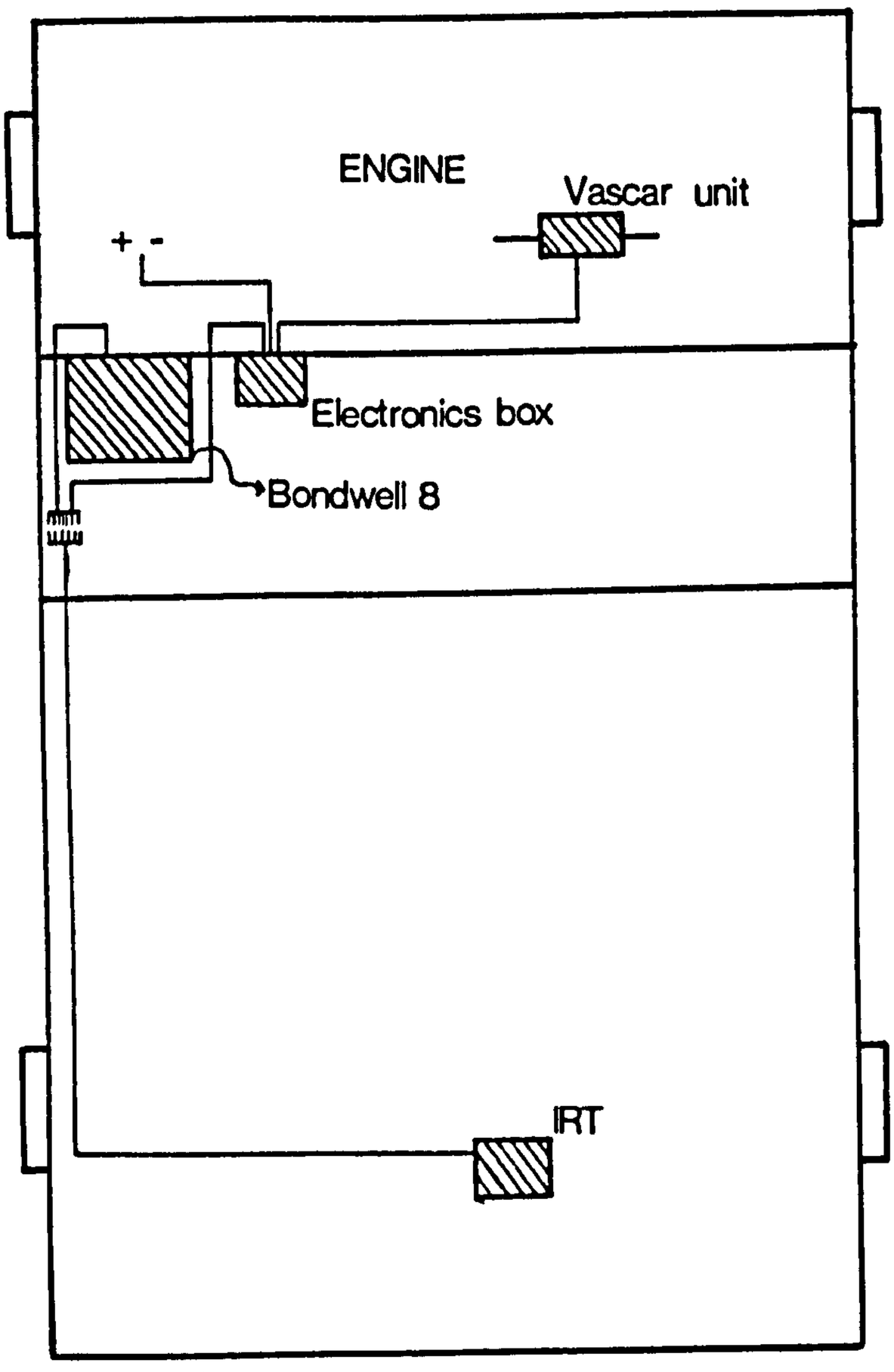
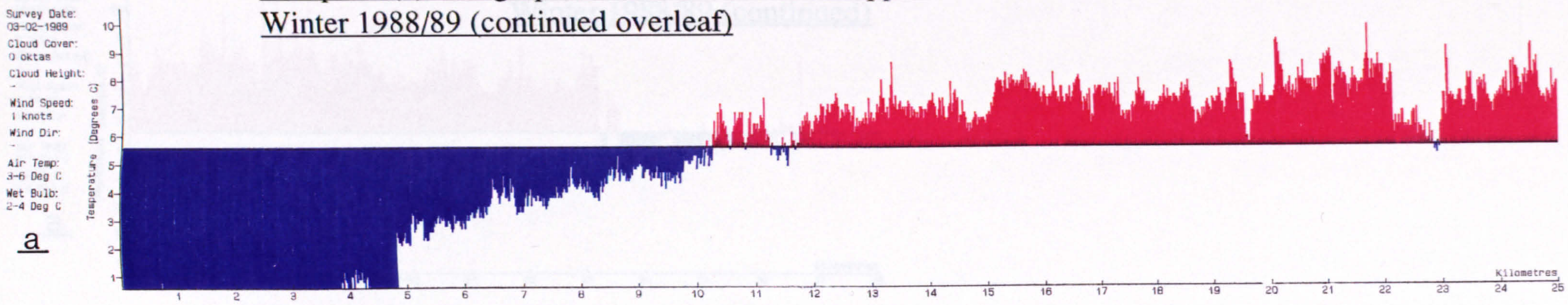


Figure 3.2: Layout Of Thermal Mapping Equipment In Van

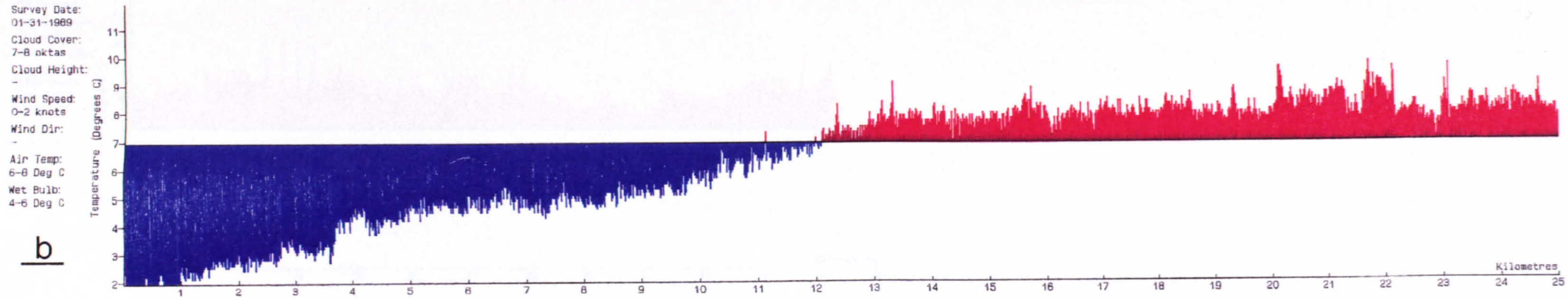


NB.not to scale

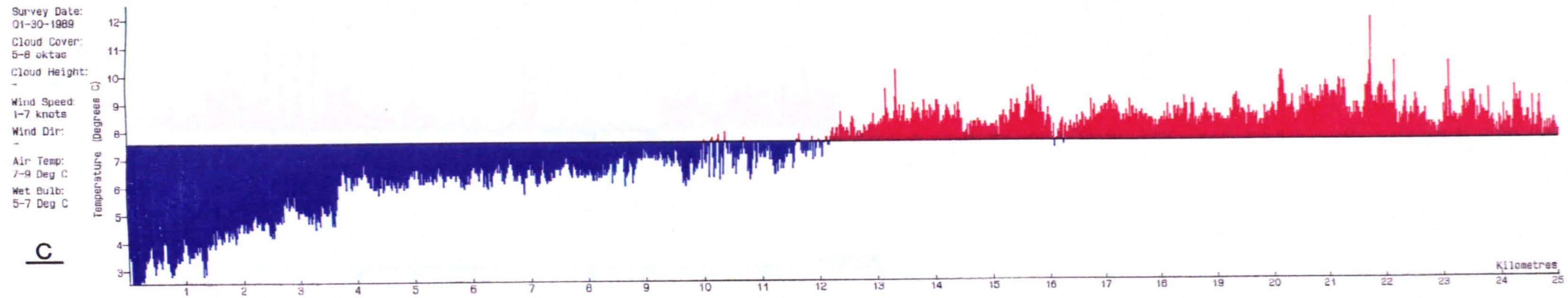
Figure 3.3: Extreme (a), Intermediate (b) and Damped (c) Fingerprints of Route 1 Mapped Winter 1988/89 (continued overleaf)



a

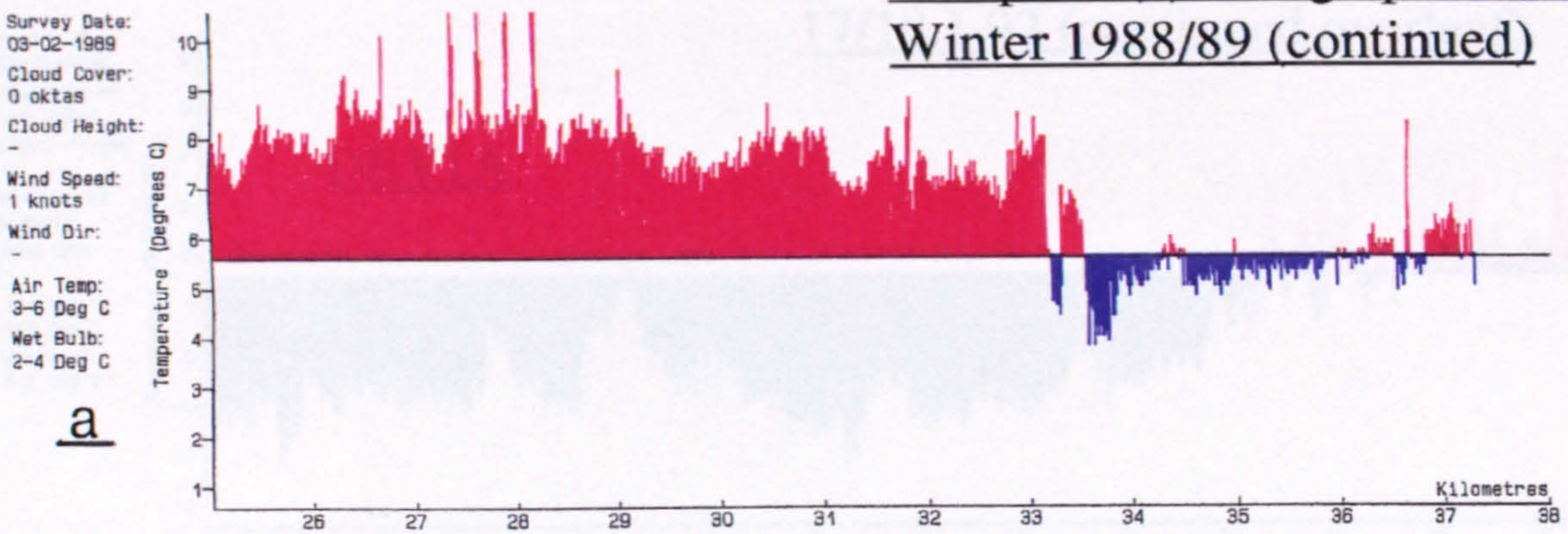


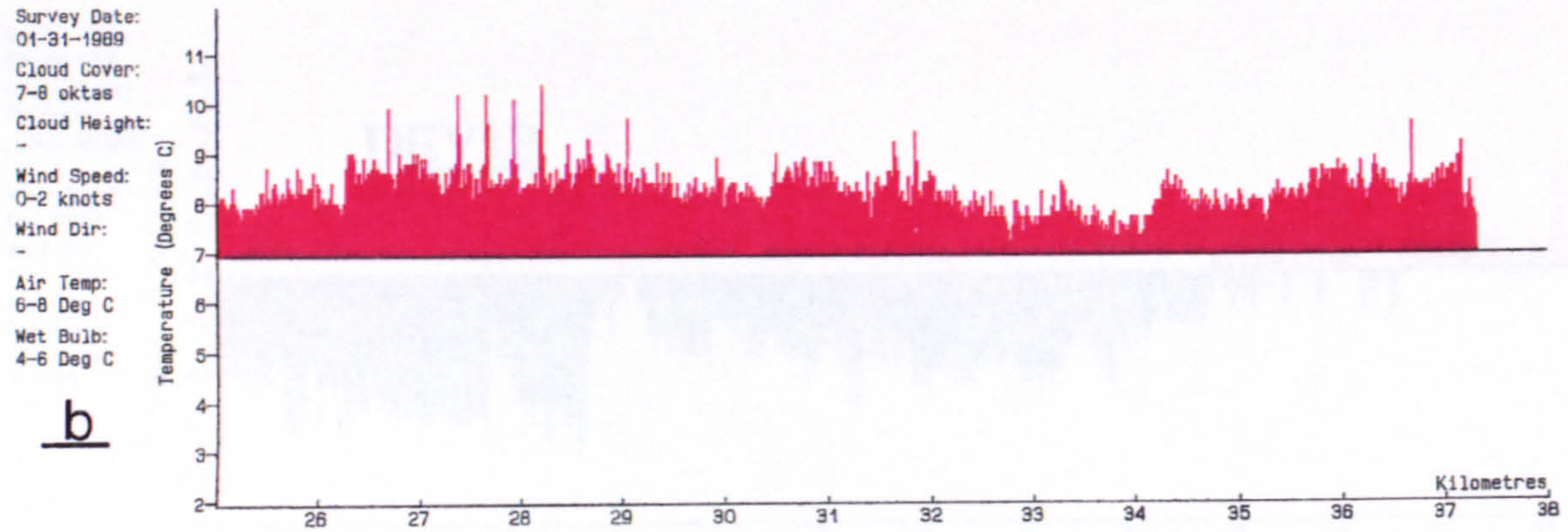
b



c

Figure 3.3: Extreme (a), Intermediate (b) and Damped (c) Fingerprints of Route 1 Mapped Winter 1988/89 (continued)





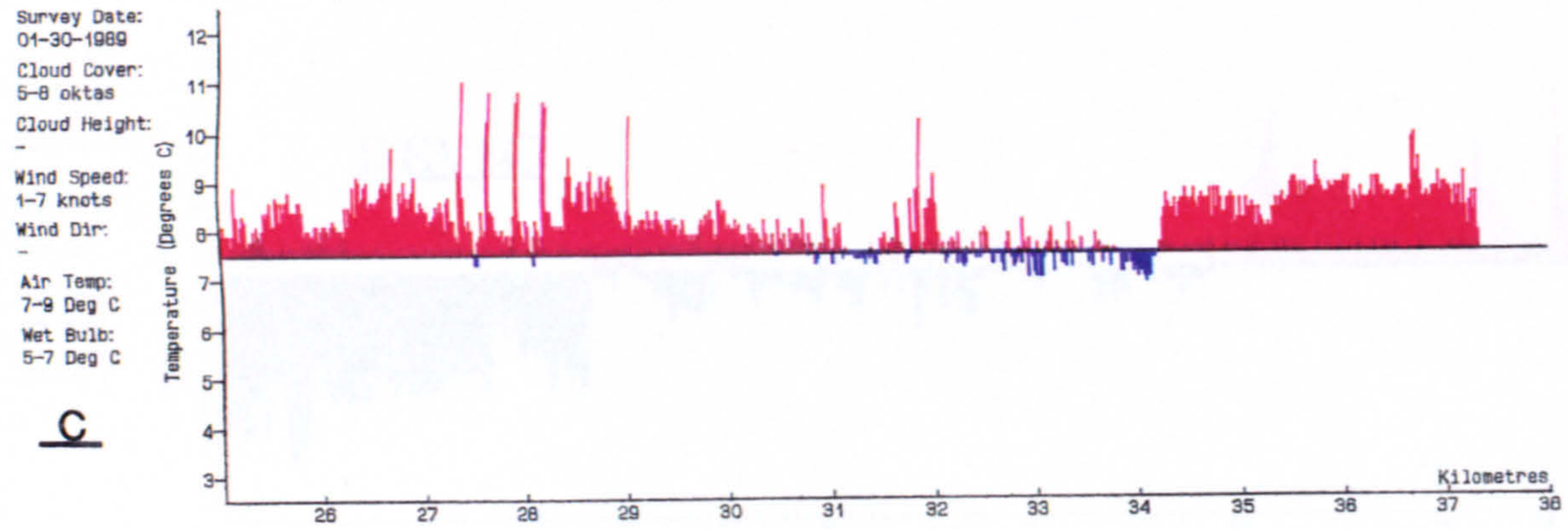
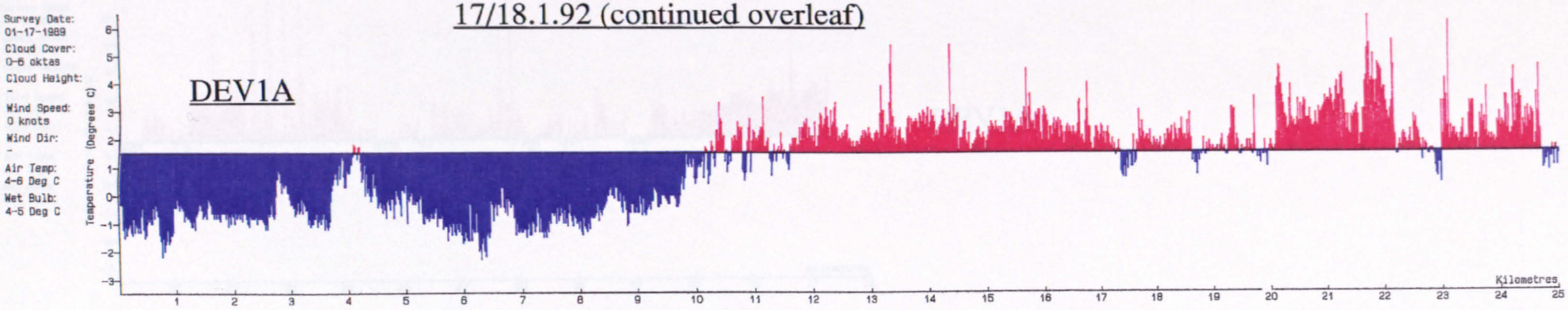
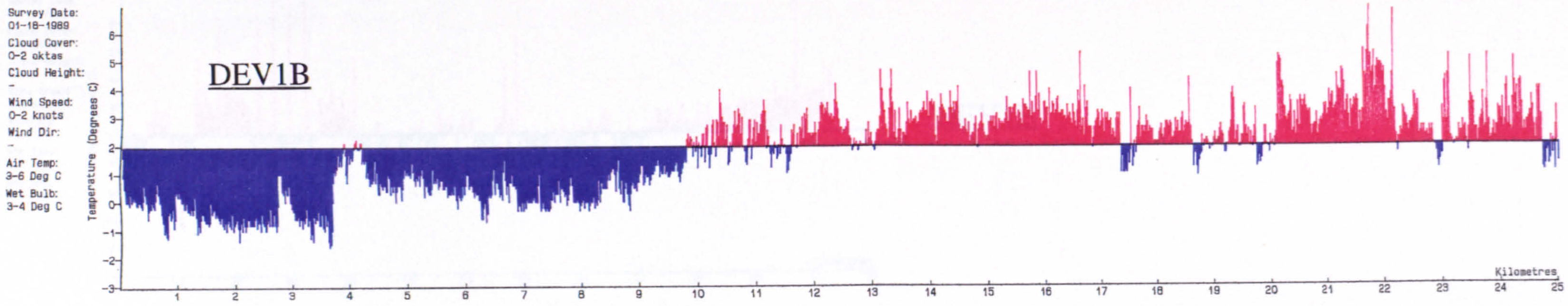


Figure 3.4: Thermal Fingerprints Mapped Night of 17/18.1.92 (continued overleaf)





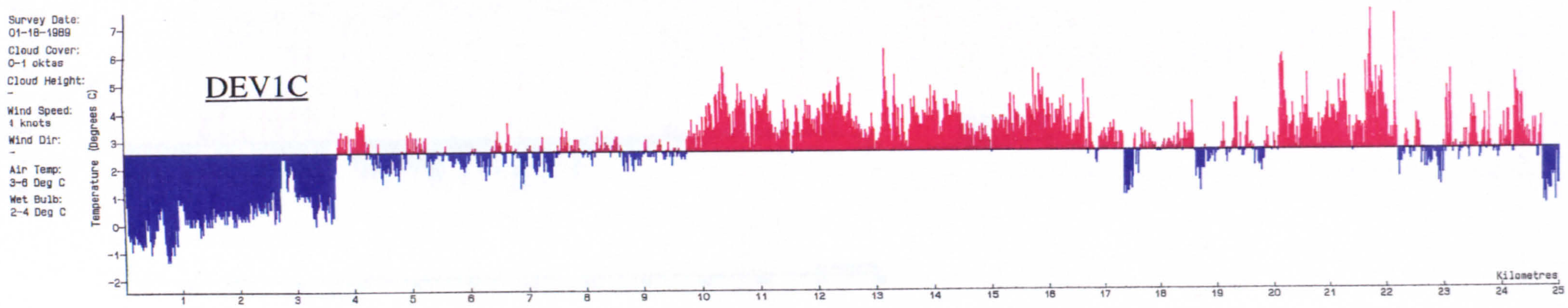
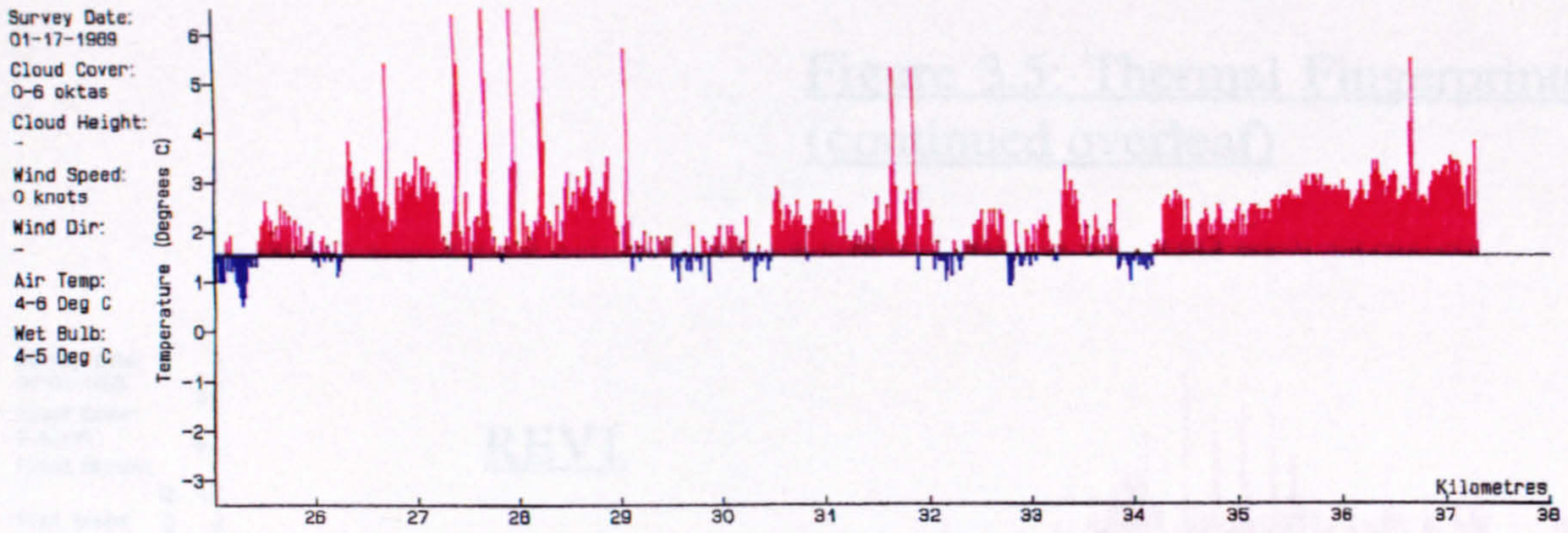
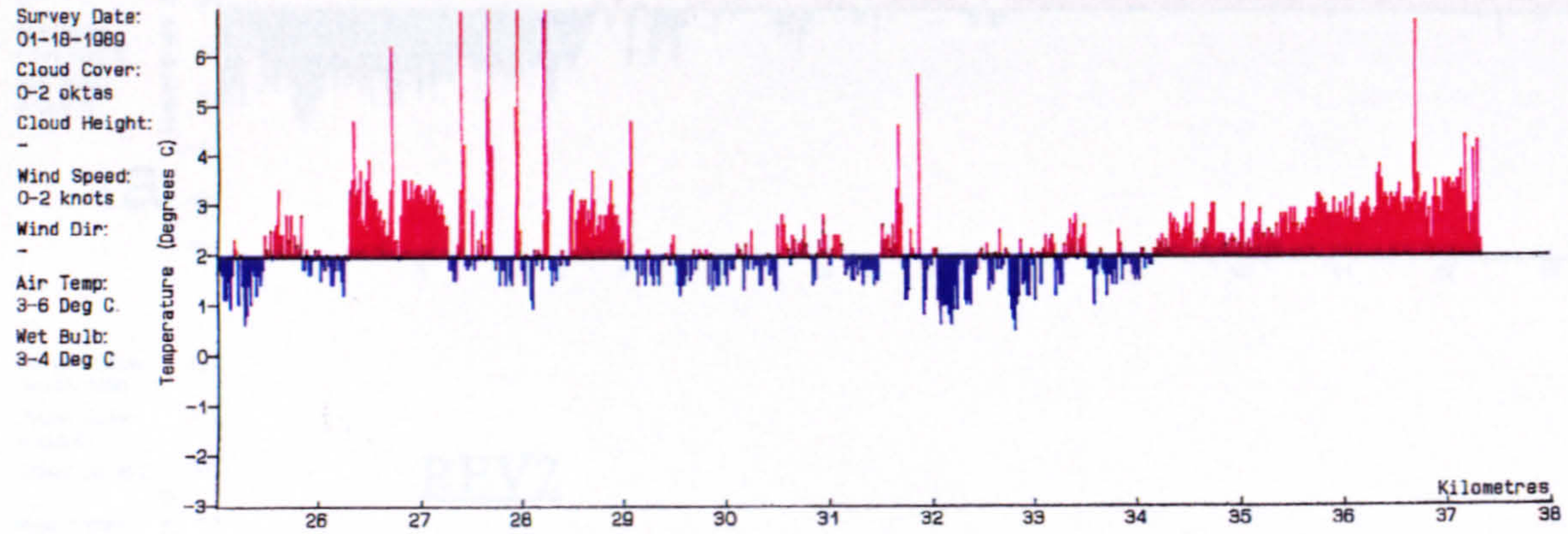


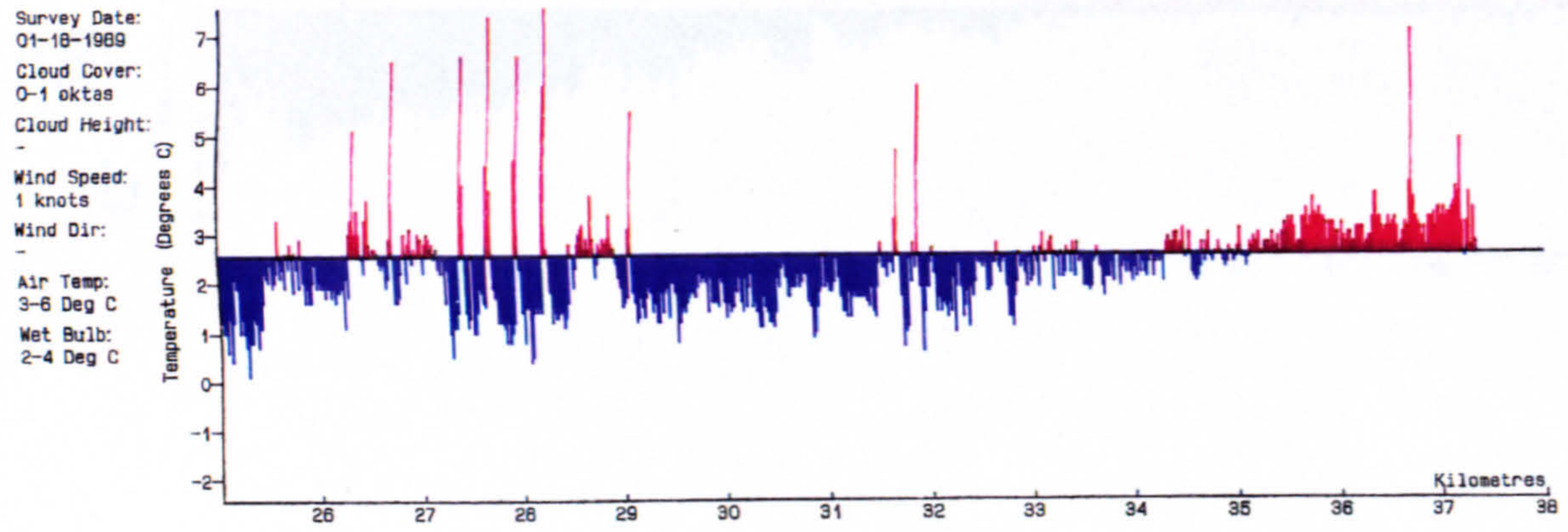
Figure 3.4: Thermal Fingerprints Mapped Night of 17/18.1.92 (continued)



DEV1A

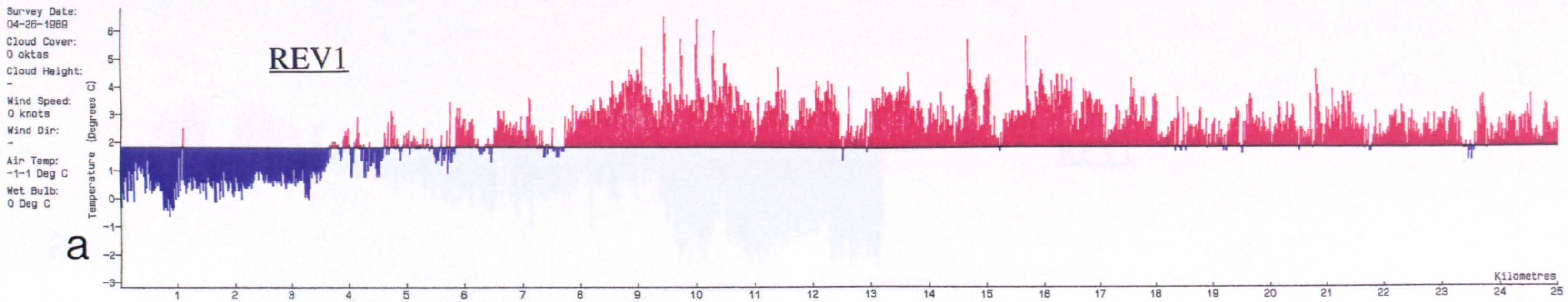


DEV1B

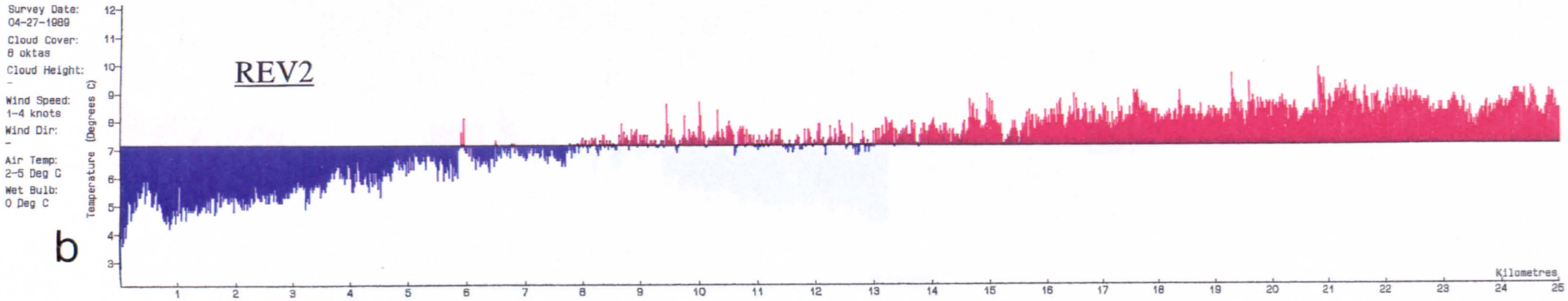


DEV1C

Figure 3.5: Thermal Fingerprints of Reverse Runs
(continued overleaf)

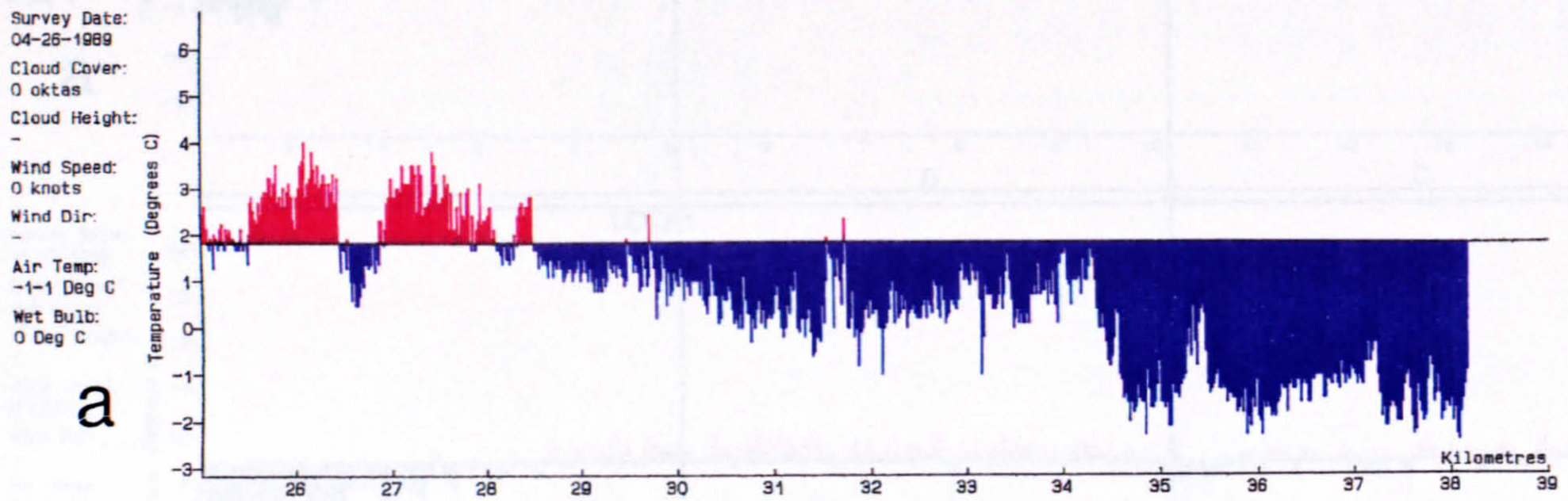


a



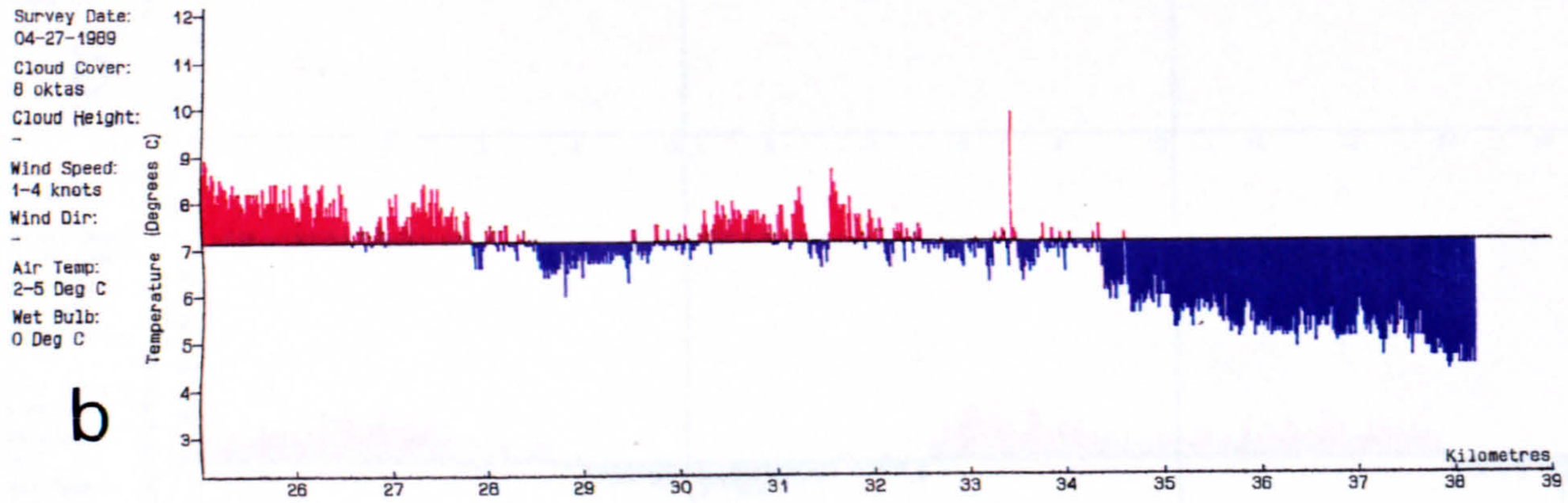
b

Figure 3.5: Thermal Fingerprints of Reverse Runs (continued)



a

REV1



b

REV2

Figure 3.6: Three Trial Runs Winter 1988/89

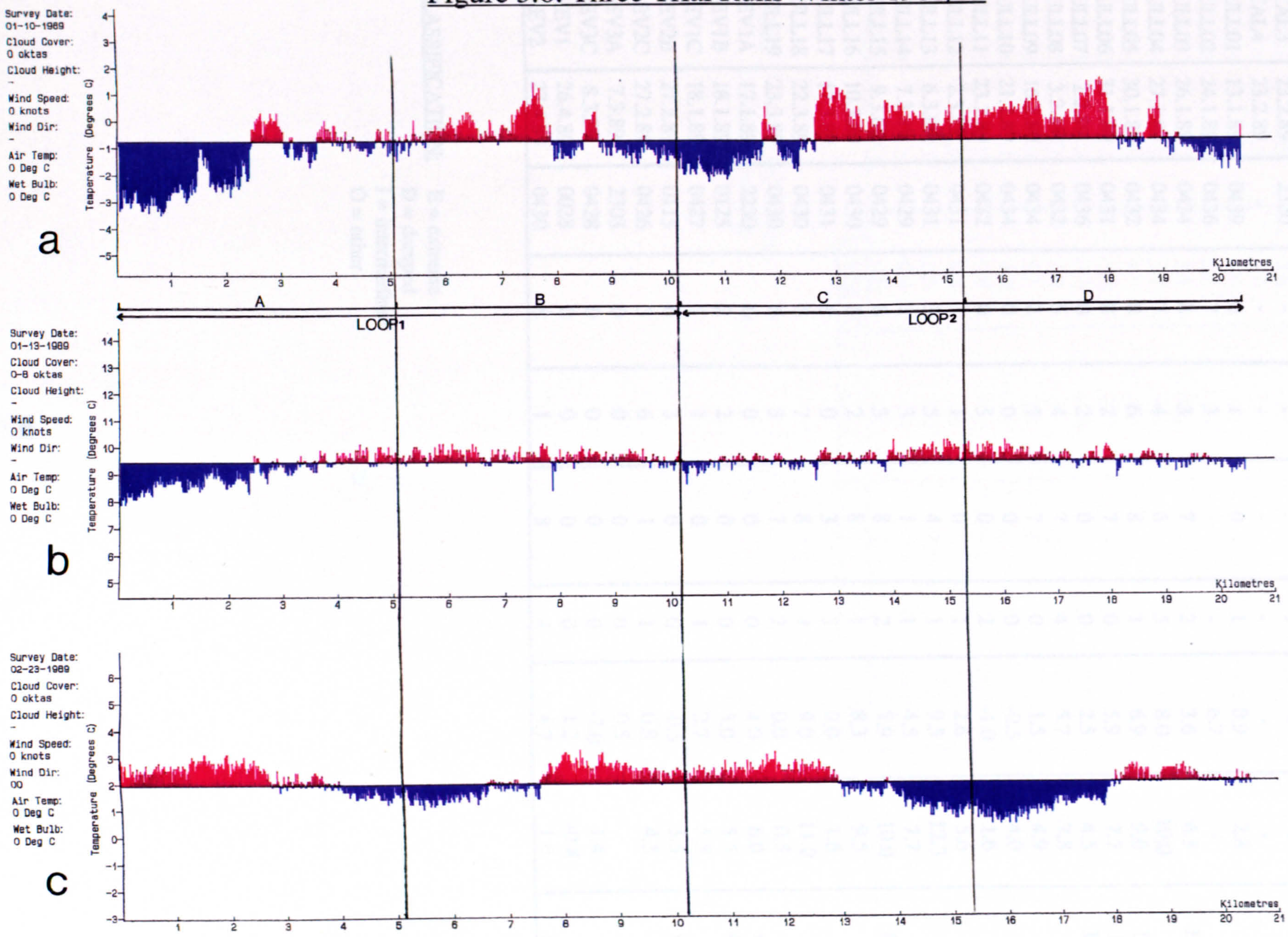


Table 3.1: Summary Of Mapping Winter 1988/89

TITLE	DATE	START TIME (HRS)	CLOUD START (OKTAS)	WIND START (M/S)	CLOUD END (OKTAS)	WIND END (M/S)	AIR TEMPERATURE START (^{O}C)	AIR TEMPERATURE END (^{O}C)	CLASS (see below)
CAL1	10.1.89	2217	0	1	0	1	-	-	E
CAL2	13.1.89	2257	8	4	8	4	-	-	D
CAL3	23.2.89	2320	-	-	-	-	-	-	O
CAL4	23.2.89	-	-	-	-	-	-	-	O
FULL01	13.1.89	0439	0	1	0	1	0.9	2.8	E
FULL02	24.1.89	0436	7	3	-	-	6.7	-	O
FULL03	26.1.89	0434	8	3	7	2	3.6	6.5	D/O
FULL04	27.1.89	0434	7	4	6	5	8.0	10.0	O
FULL05	30.1.89	0432	8	6	8	1	6.9	9.0	D/O
FULL06	31.1.89	0431	8	2	7	0	5.9	7.7	I/O
FULL07	2.2.89	0436	0	2	0	0	2.5	4.5	E/O
FULL08	3.2.89	0432	5	4	7	4	5.7	7.8	O
FULL09	16.2.89	0434	2	5	7	0	1.5	4.9	O
FULL10	21.2.89	0434	0	0	0	0	-0.5	4.0	E
FULL11	23.2.89	0432	0	5	0	2	-1.0	1.6	O
FULL12	2.3.89	0431	1	1	0	1	2.6	5.6	E
FULL13	6.3.89	0431	3	5	4	1	9.5	12.3	O
FULL14	7.3.89	0429	1	3	1	1	4.5	7.7	O
FULL15	9.3.89	0429	8	5	8	2	7.9	10.0	D/O
FULL16	10.3.89	0430	8	2	8	1	8.3	9.5	O
FULL17	17.3.89	0431	0	0	3	3	0.0	1.6	O
FULL18	22.3.89	0430	8	7	8	4	9.0	11.0	D
FULL19	23.3.89	0430	6	3	7	2	0.0	0.5	O
DEV1A	17.1.89	2230	6	0	0	0	4.0	6.0	O/E
DEV1B	18.1.89	0125	2	2	0	0	3.0	5.5	O/E
DEV1C	18.1.89	0427	1	1	0	1	2.7	5.5	E
DEV2B	27.2.89	0115	0	3	0	0	-0.5	3.5	O/E
DEV2C	27.2.89	0426	3	6	1	1	0.8	4.5	O
DEV3A	7.3.89	2303	0	0	0	0	0.5	-	E
DEV3C	8.3.89	0428	0	0	0	0	-2.0	1.4	E
REV1	26.4.89	0028	0	0	0	0	1.2	-0.8	E
REV2	27.4.89	0430	8	1	8	4	4.7	1.6	D/O

CLASSIFICATION: E = extreme
D = damped
I = intermediate
O = other

Table 3.2: Air And Road Temperatures Recorded At The Start And End Of Mapping Runs 1988/89

RUN	RST_1	START AIR TEMP.	DIFF. (RST-AIR)	RST_2	END AIR TEMP.	DIFF. (RST-AIR)
FULL01	-2.4	0.9	-3.3	2.2	2.8	-0.6
FULL02	-	-	-	-	-	-
FULL03	0.9	3.6	-2.7	4.0	6.5	-2.5
FULL04	4.2	8.0	-3.8	7.1	10.0	-2.9
FULL05	3.4	6.9	-3.5	7.9	9.0	-1.1
FULL06	1.8	5.9	-4.1	7.7	7.7	0.0
FULL07	-2.3	2.5	-4.8	1.2	4.5	-3.3
FULL08	2.2	5.7	-3.5	6.7	7.8	-1.1
FULL09	-2.4	1.5	-3.9	4.0	4.9	-0.9
FULL10	-3.5	-0.5	-3.0	2.0	4.0	-2.0
FULL11	-5.6	-1.0	-4.6	1.7	1.6	0.1
FULL12	-0.4	2.6	-3.0	5.0	5.6	-0.6
FULL13	5.9	9.5	-3.6	9.3	12.3	-3.0
FULL14	2.1	4.5	-2.4	6.1	7.7	-1.6
FULL15	3.8	7.9	-4.1	8.1	10.0	-1.9
FULL16	5.5	8.3	-2.8	9.2	9.5	-0.3
FULL17	-3.0	0.0	-3.0	1.0	1.6	-0.6
FULL18	5.5	9.0	-3.5	9.1	11.0	-1.9
FULL19	-4.1	0.0	-4.1	2.7	0.5	2.2
		AVERAGE:	-3.54		AVERAGE:	-1.22

NOTES: 1) Second IRT reading.
2) Last IRT reading.

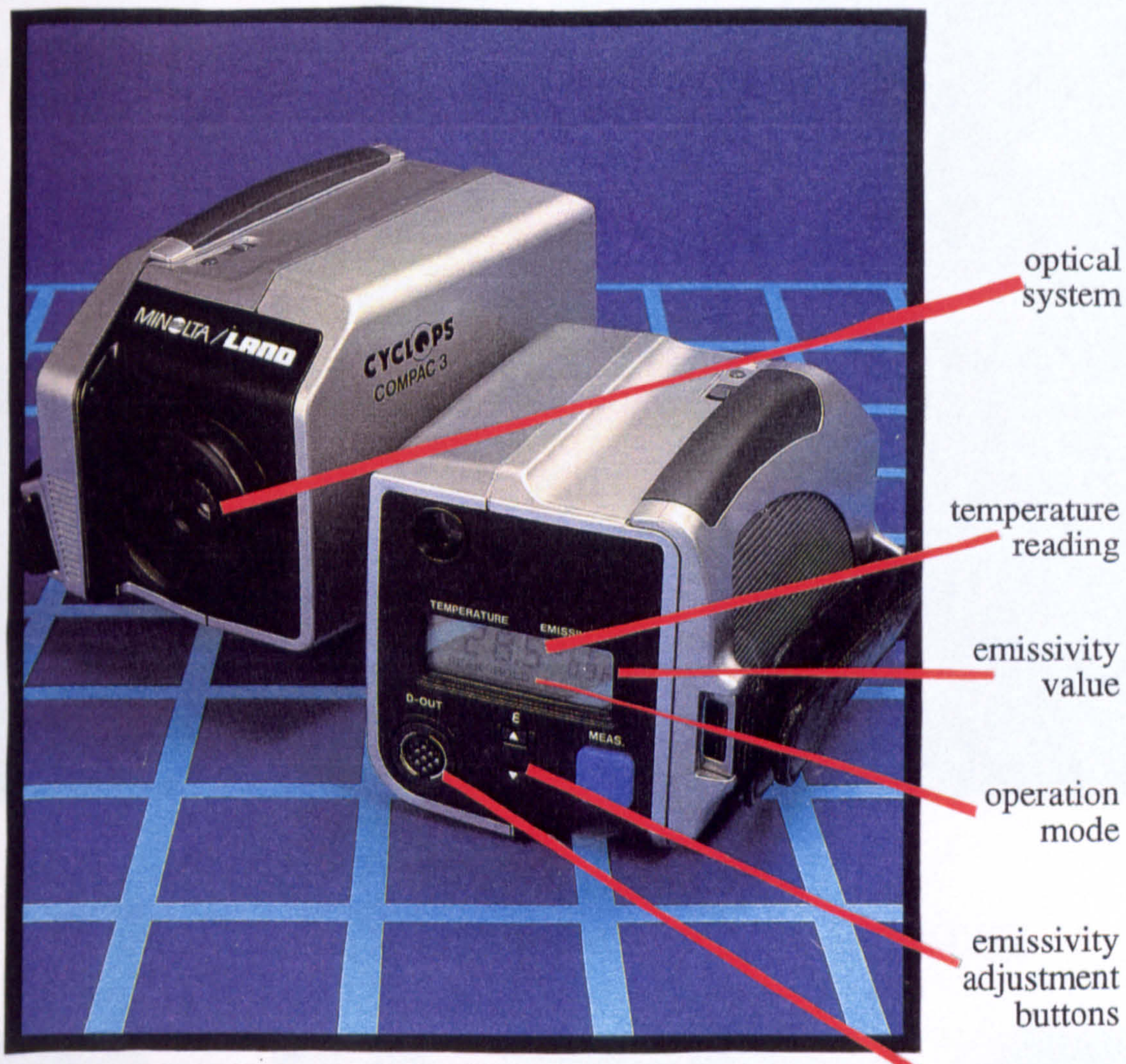
Table 3.3: Details Of Runs Made Nights Of 17/18.1.89 And 7/8.3.89

DATE	TITLE	START TIME (HRS)	CLOUD START (OKTAS)	WIND START (M/S)	CLOUD END (OKTAS)	WIND END (M/S)	START AIR TEMP. (^{O}C)	END AIR TEMP. (^{O}C)	AV. ROAD TEMP. (^{O}C)
17.1.89	DEV1A	2230	6	0	0	0	4.0	6.0	1.6
18.1.89	DEV1B	0125	2	2	0	0	3.0	5.5	1.9
18.1.89	DEV1C	0427	1	1	0	1	2.7	5.5	2.6
7.3.89	DEV3A	2303	0	0	0	0	0.5	3.0	1.0
8.3.89	DEV3C	0428	0	0	0	0	-2.0	1.4	2.3

Table 3.4: Differences Between Icelert Readings And Infra-Red Thermometer Readings For Mapping Runs Winter 1988/89

RUN	DIFFERENCE (+VE = ICELERT WARMER)				MOSCAR MINUS PRINCE
	MOSCAR TOP	HILLFOOT	TINSLEY	PRINCE OF WALES ROAD	
FULL05	1.2	-1.3	-2.1	1.8	-0.6
FULL07	3.7	-	-	-	-
FULL08	-	-	-1.6	-1.3	-
FULL10	4.6	-	1.3	-	-
FULL11	3.9	-	1.0	0.7	3.2
FULL12	0.6	-	-3.9	-4.2	4.8
FULL13	1.5	-	-0.3	-0.4	1.9
FULL14	2.2	-	1.5	0.9	1.3
FULL15	0.9	-	-0.1	-0.2	1.1
FULL16	1.2	-	0.4	0.4	1.6
FULL17	3.1	-	1.5	0.6	3.7
FULL18	1.1	-	-0.5	-0.2	1.3
DEV2C	1.1	-	-1.6	1.5	-0.4
DEV3C	0.8	-	1.7	1.2	-0.4
REV1	1.3	-	-	2.5	-1.2
REV2	-1.0	-	-	-0.5	-0.5

Photo 3.1: Minolta/LAND Cyclops Compac 3 Infra-Red Thermometer



SOURCE: Minolta/LAND Compac 3
Instrument Brochure

Photo 3.2: Equipment Used For Data Collection Winter 1988/89

Photo 3.3: Vascar Unit Located Between Split Speedometer Cable

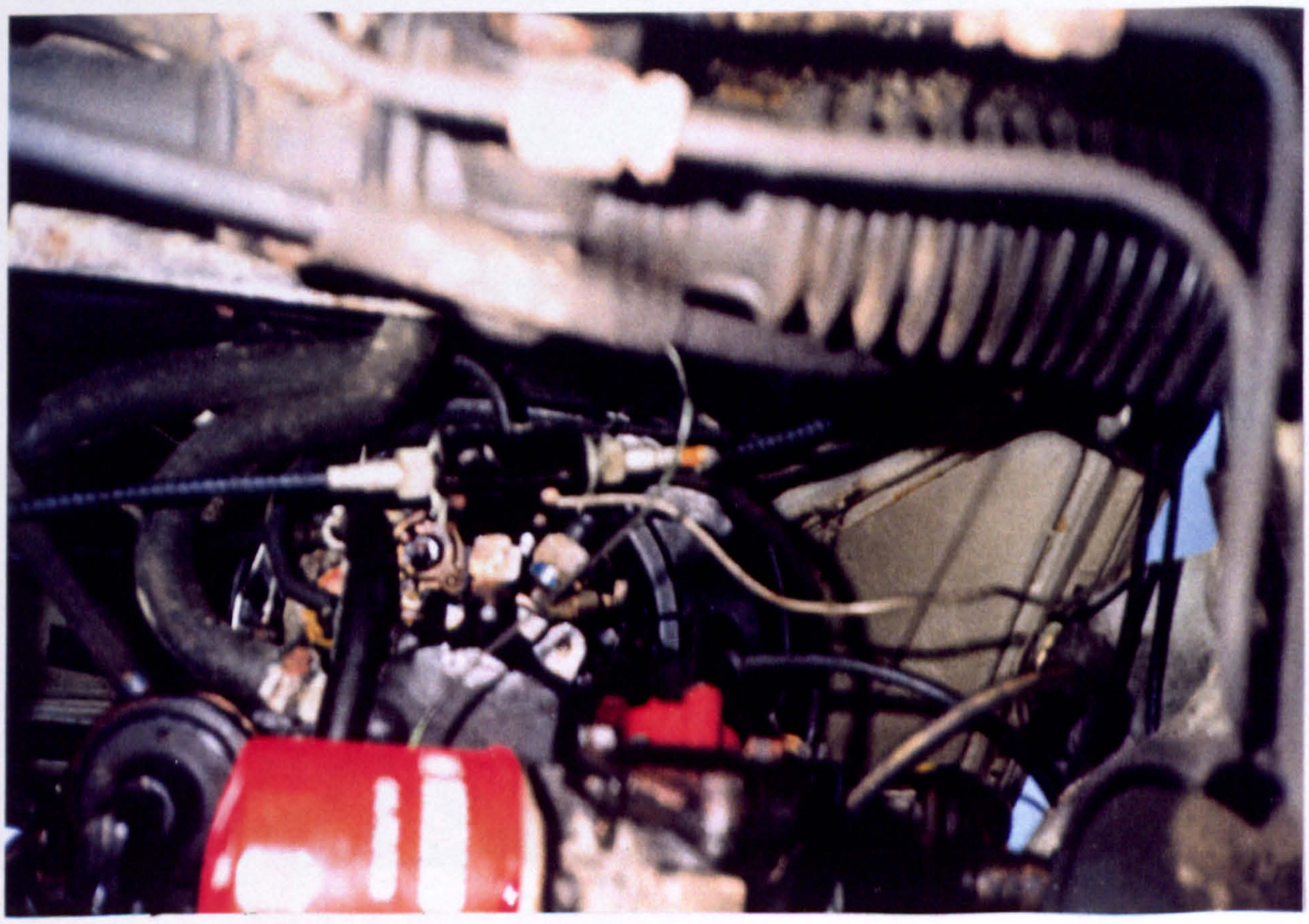


Photo 3.4: Electronics Box And Computer Mounting In Van

Photo 3.5: IRT On Mounting In Back Of Van

Photo 3.6: Testing Performance Of IRT Using Melting Ice (I) As Target

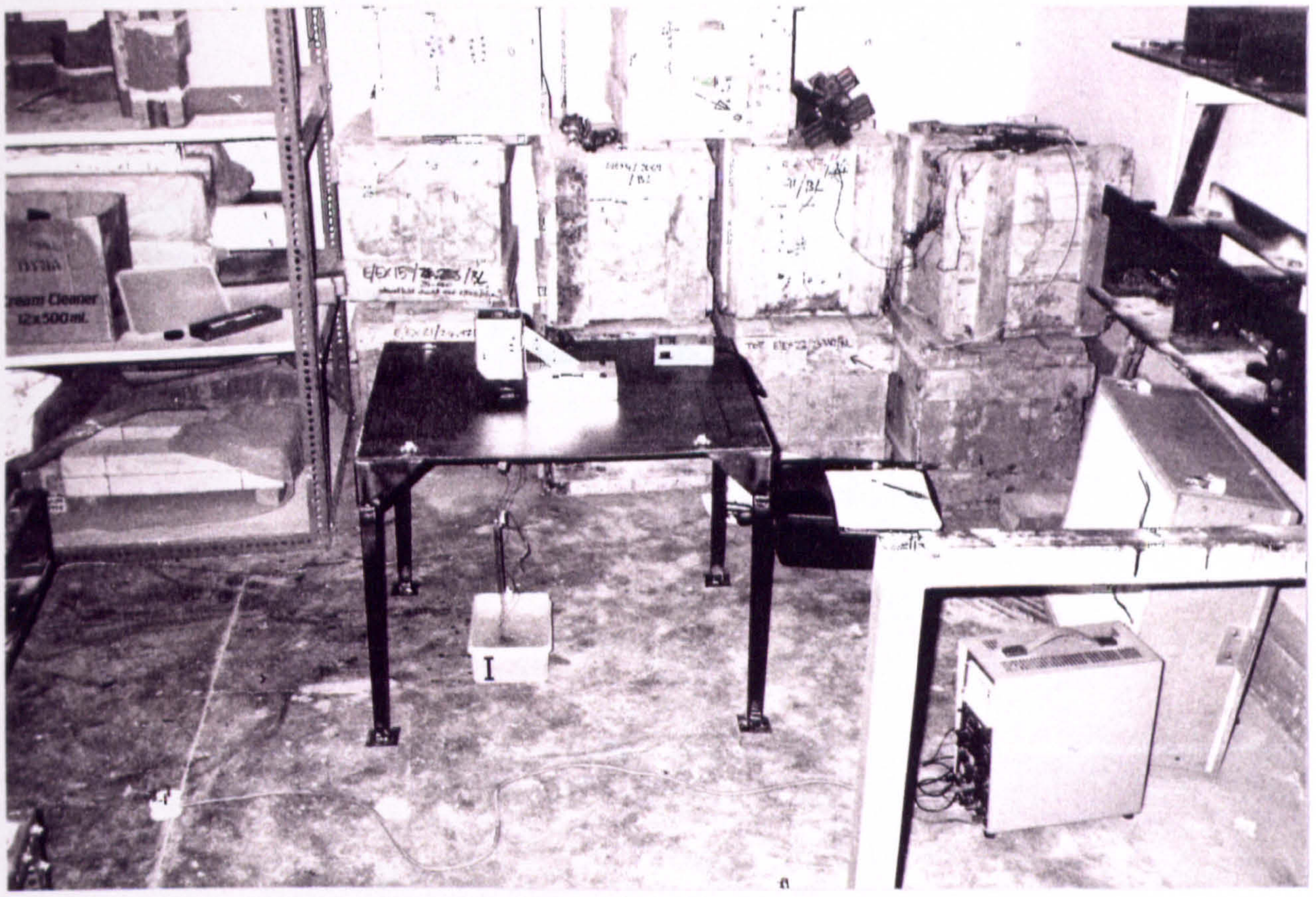
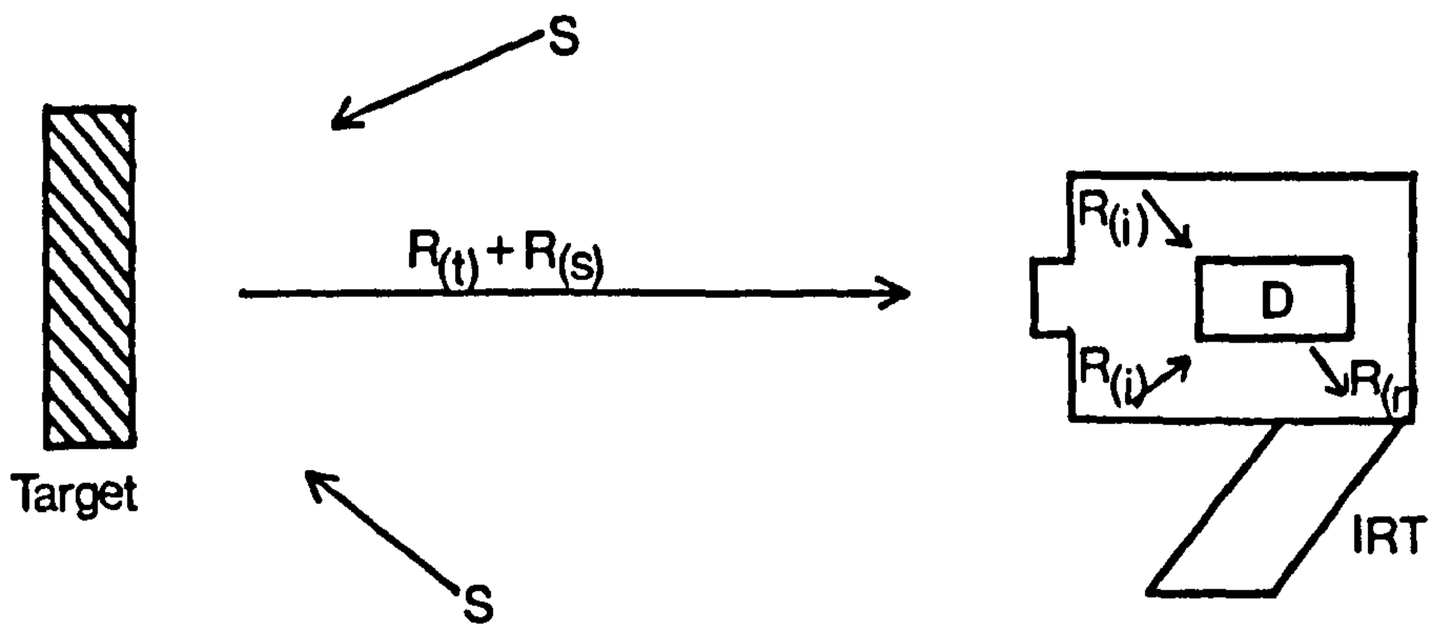


Photo 3.7: Location Of Tinsley Icelert Sensor

CHAPTER 4

Figure 4.1: Sources of Infra-red Radiation Detected by the IRT



KEY

D = detector

$R_{(t)}$ = radiation emitted by target

S = radiation emitted by surrounds

$R_{(s)}$ = radiation emitted by surrounds and reflected off target

$R_{(i)}$ = radiation emitted by instrument itself

$R_{(r)}$= radiation re-emitted by detector

Figure 4.2: Side View of Temperature Control Box

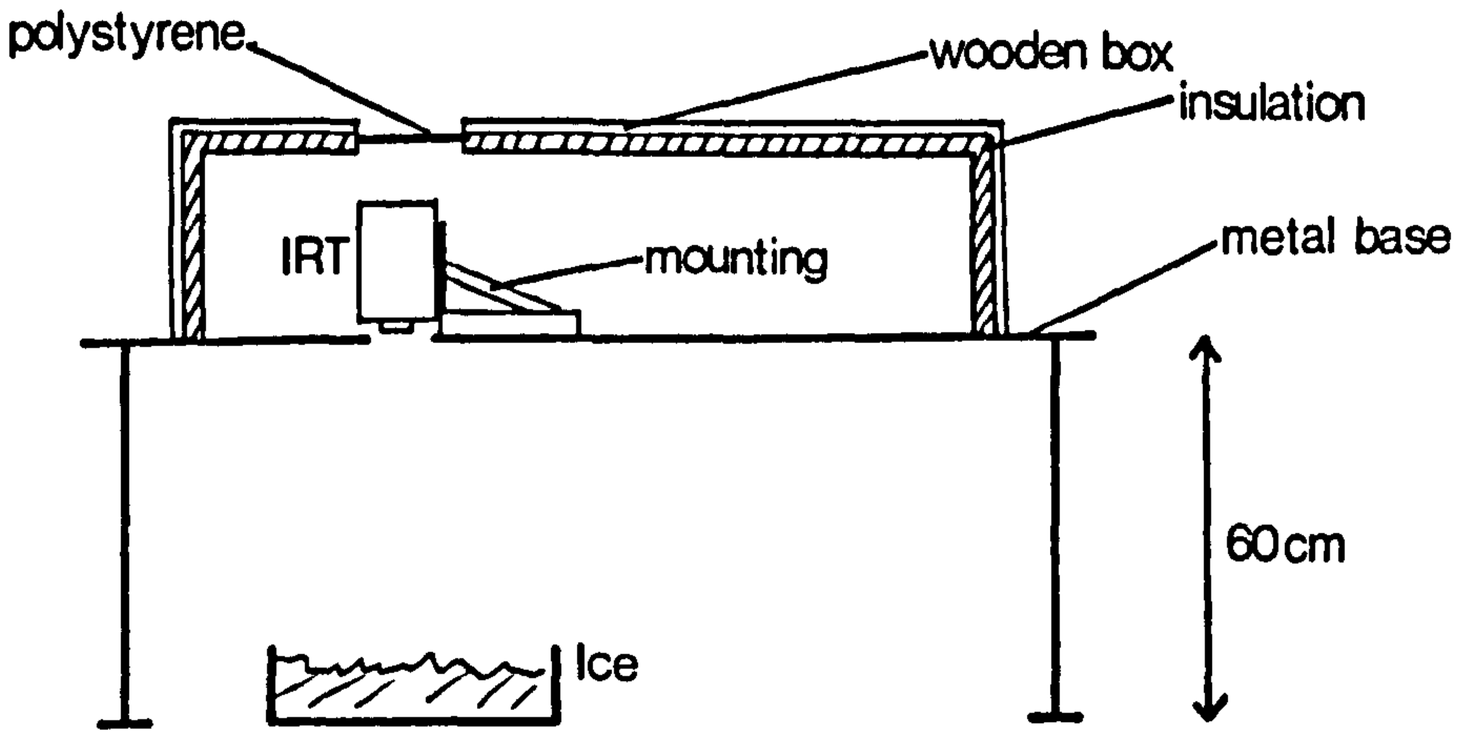


Figure 4.3: Plan View of Temperature Control Box

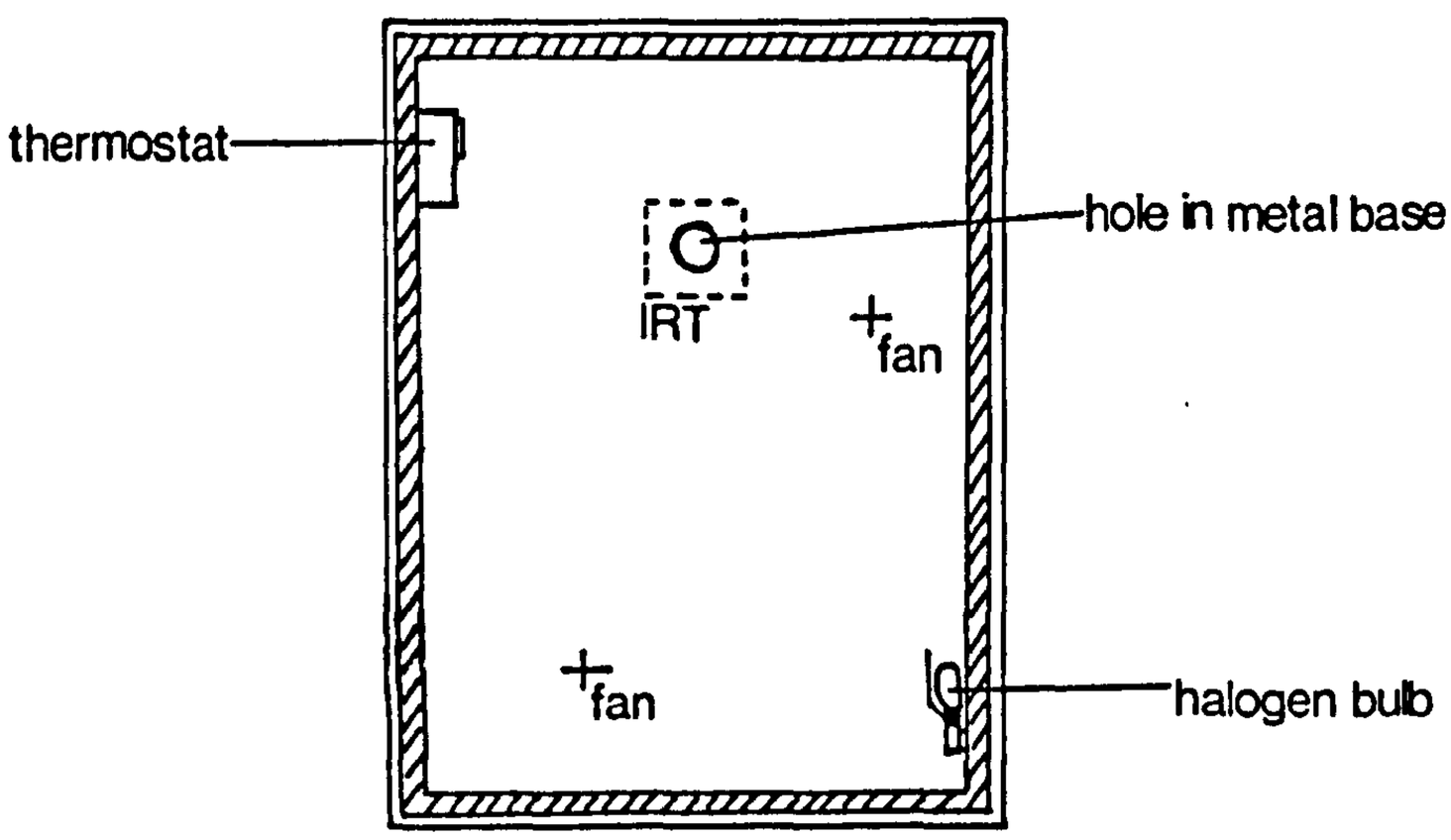


Figure 4.4: Results of Laboratory Test A1

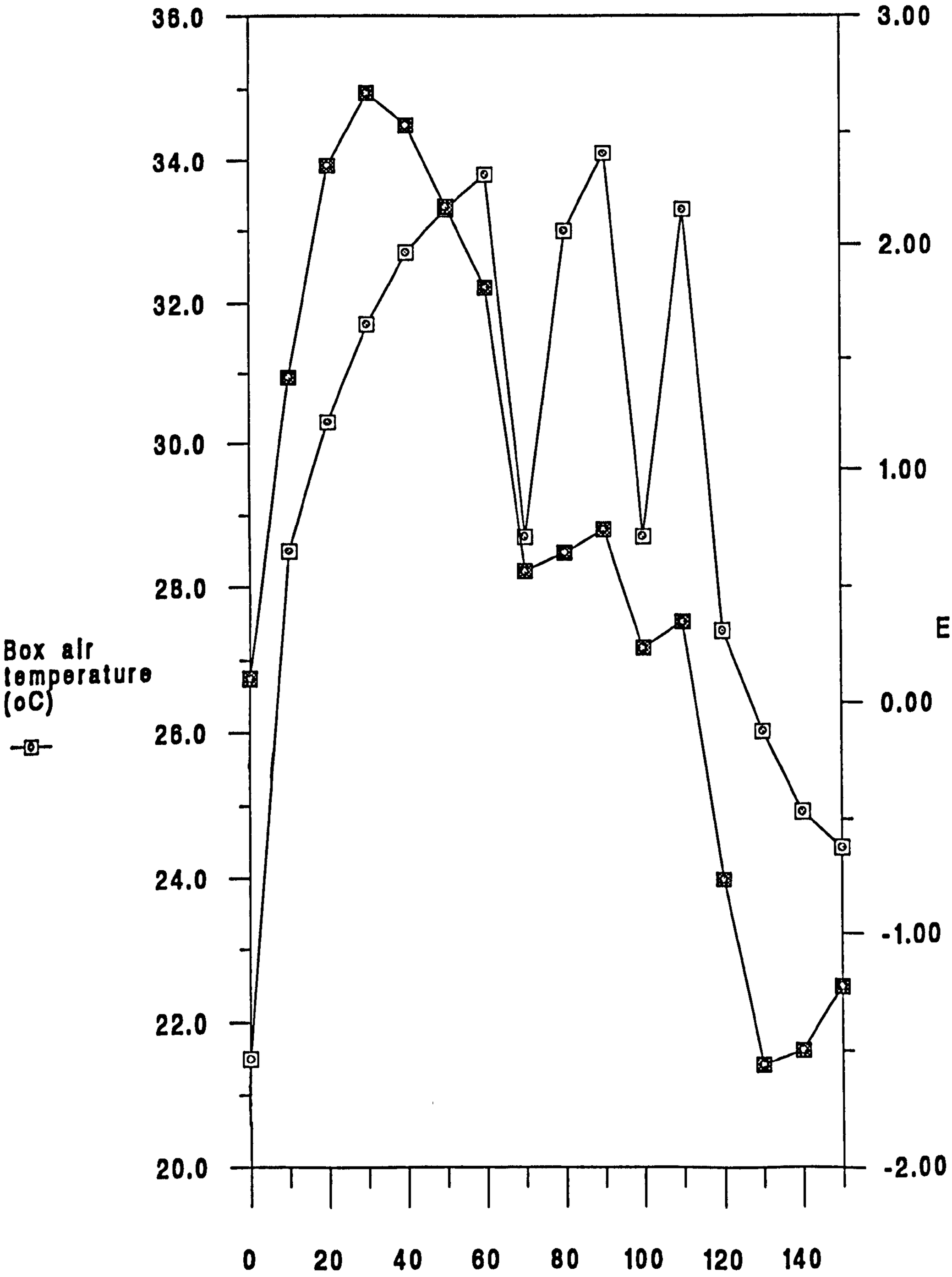


Figure 4.5: Results of Laboratory Test B1

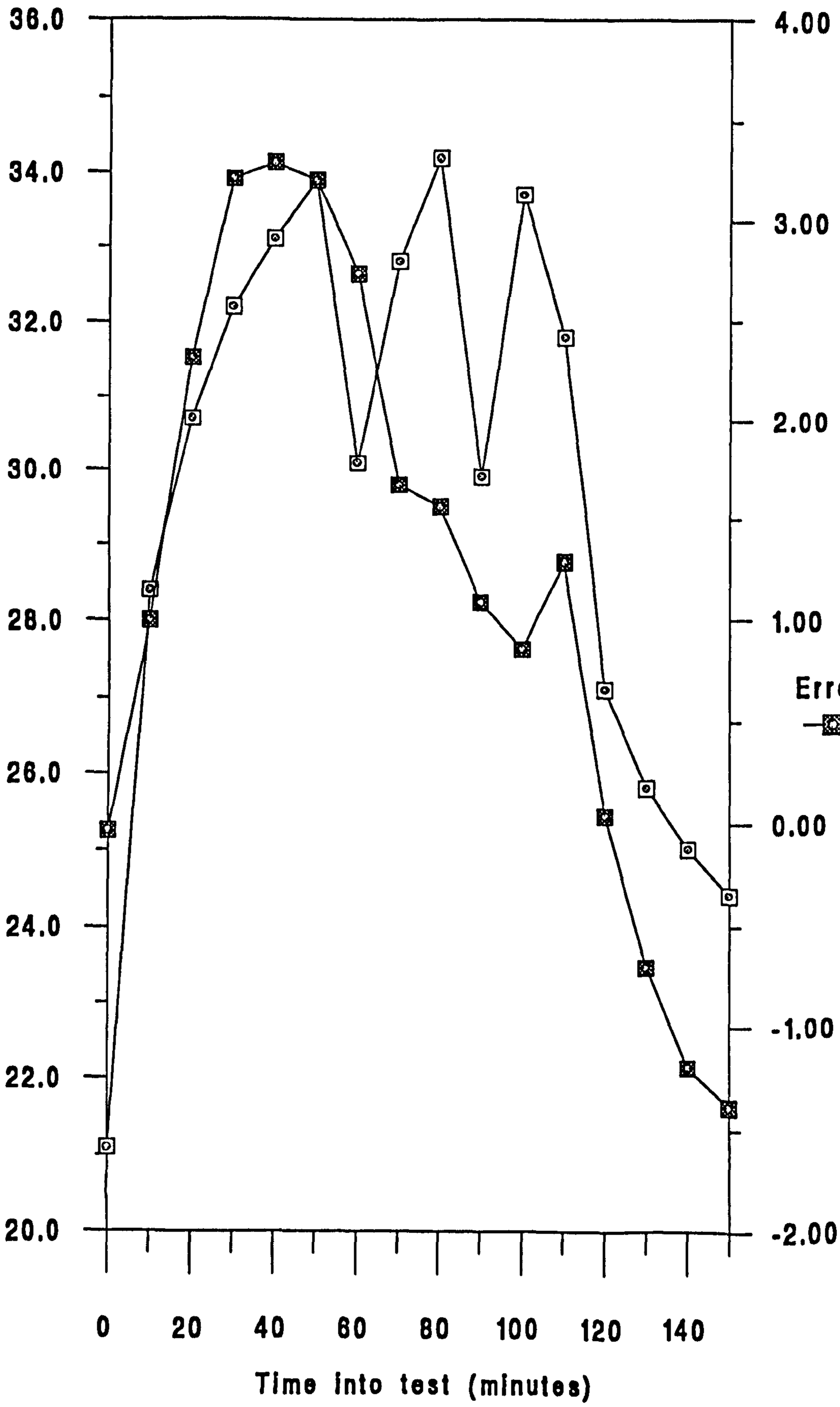


Figure 4.6: Results of Subsidiary Laboratory Test

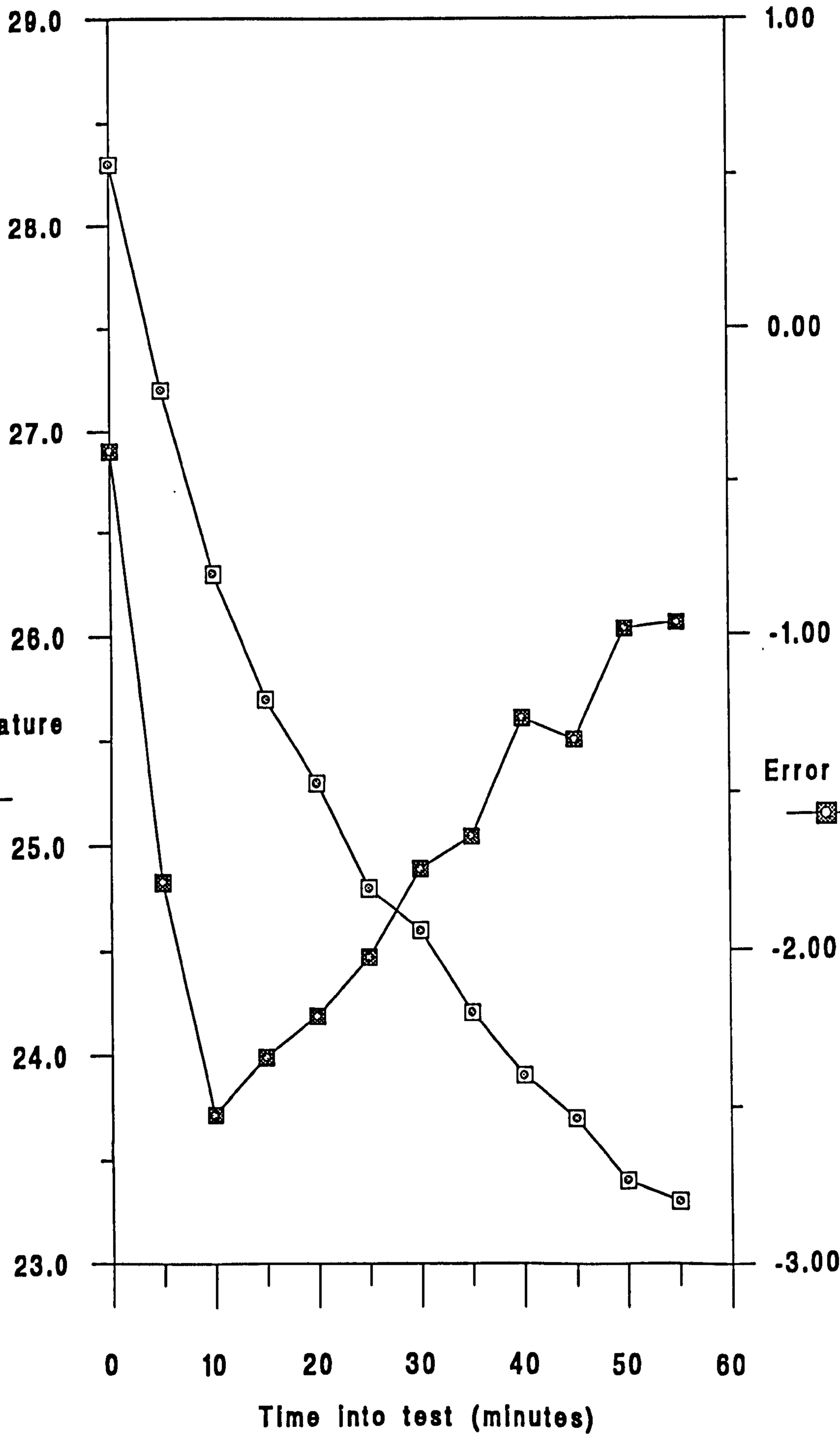


Figure 4.7: Results of Laboratory Test C1

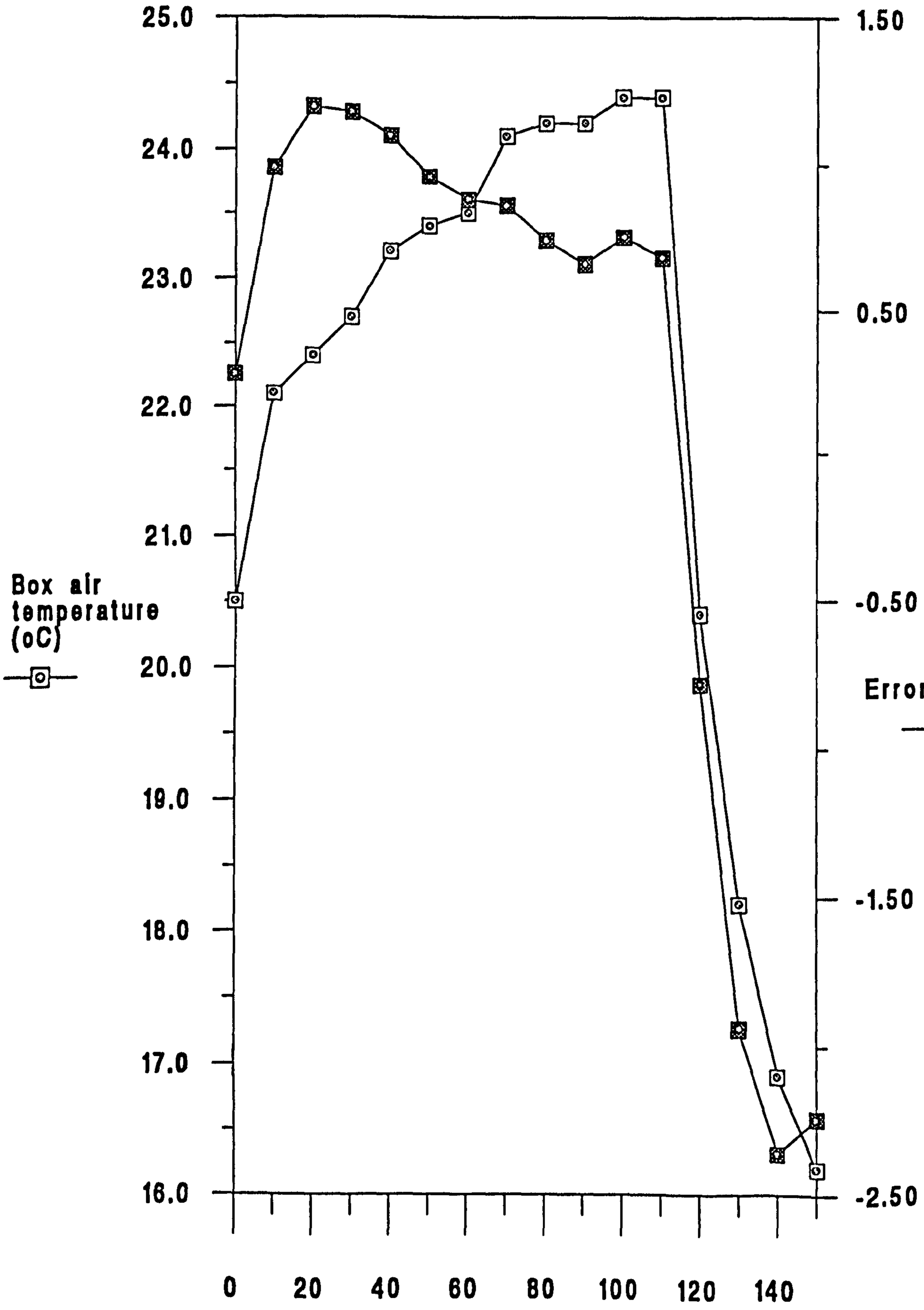


Figure 4.8: Plot of Box Air Warming Rate and Error In IRT Reading

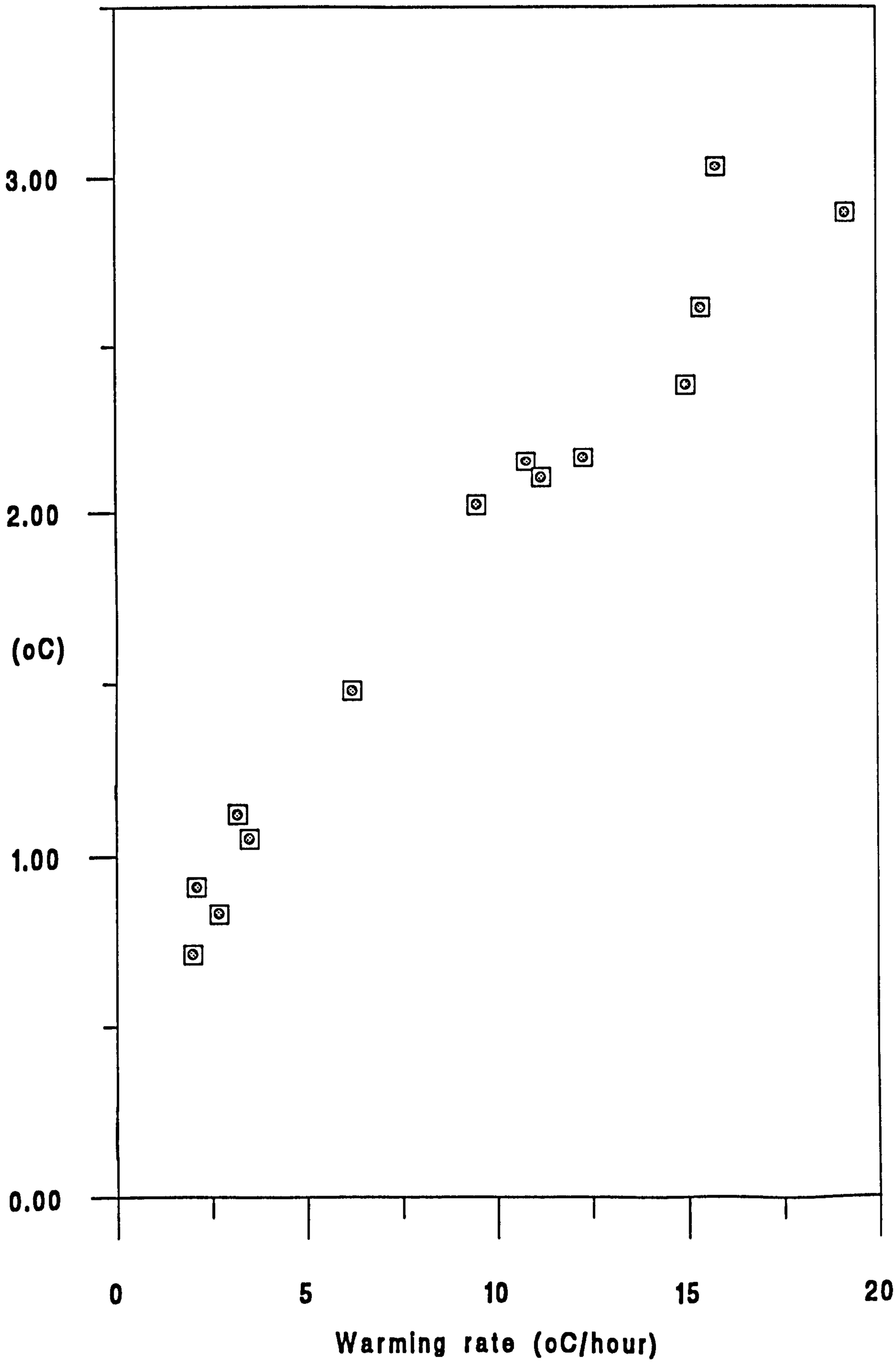


Figure 4.9: Plot of Box Air Cooling Rate And Error In IRT Reading

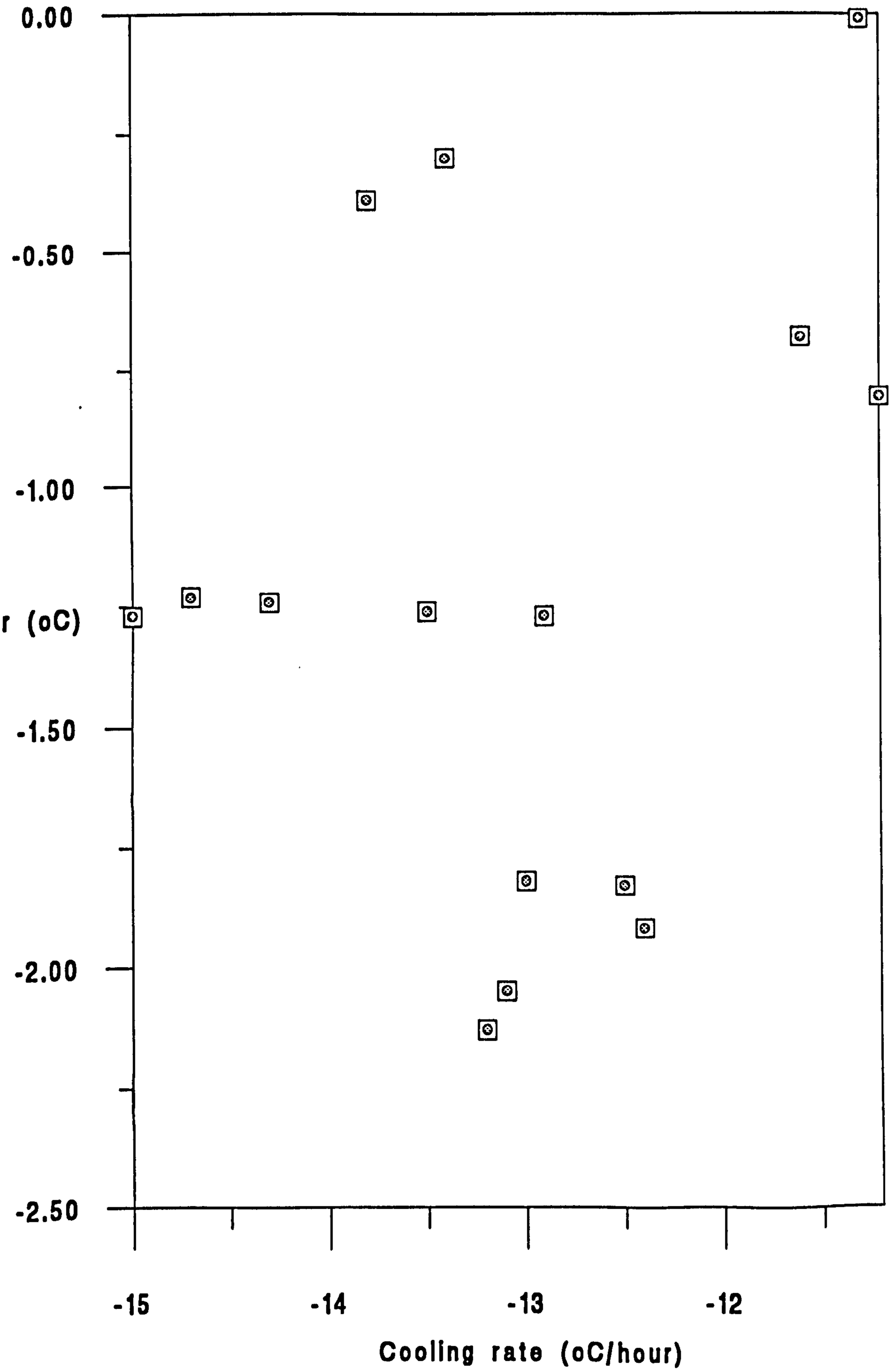


Figure 4.10: Plot of IRT Warming Rate and Error

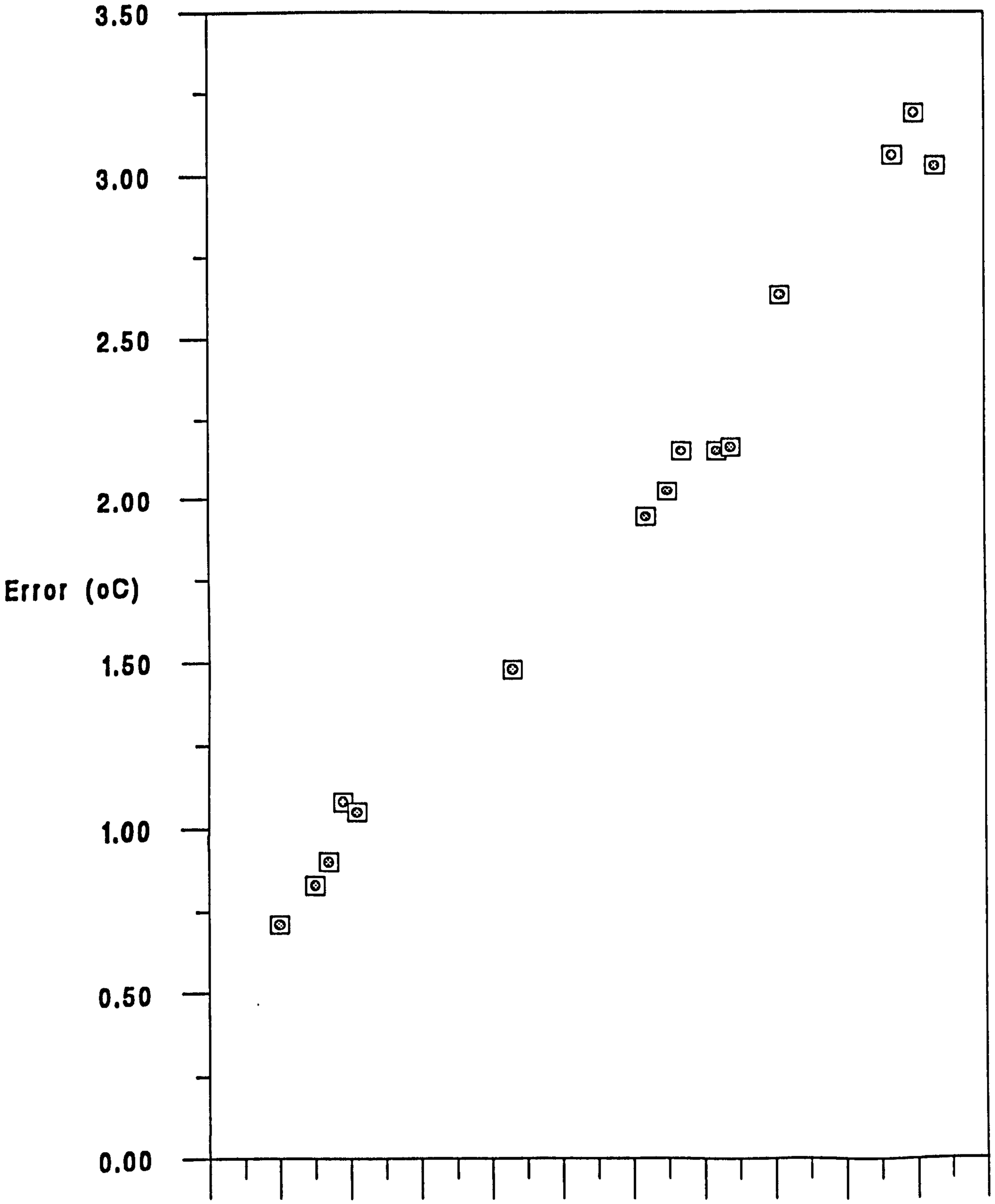


Figure 4.11: Plot of IRT Cooling Rate and Error

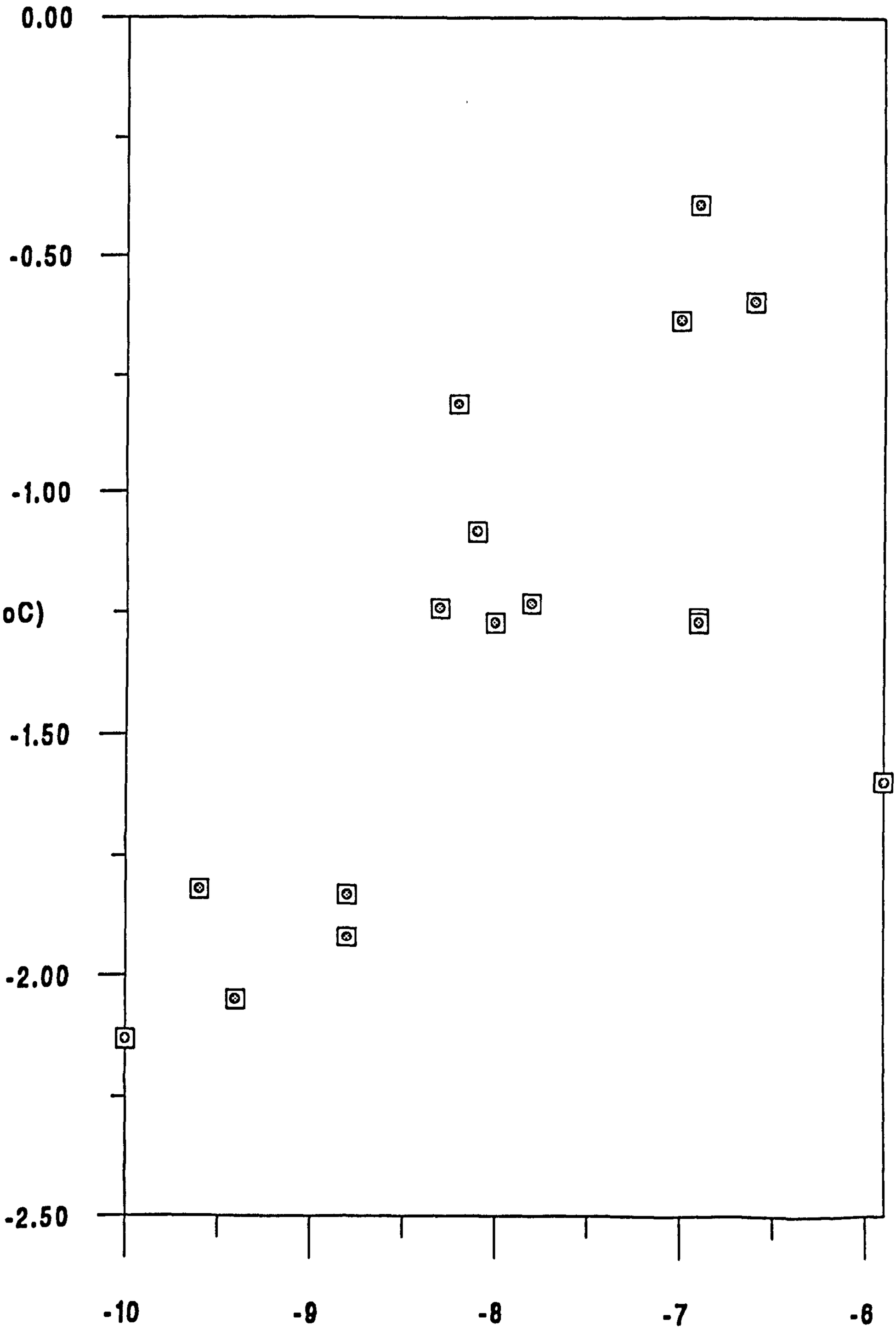


Figure 4.12: Plot of Warming/Cooling Rate of IRT and Error

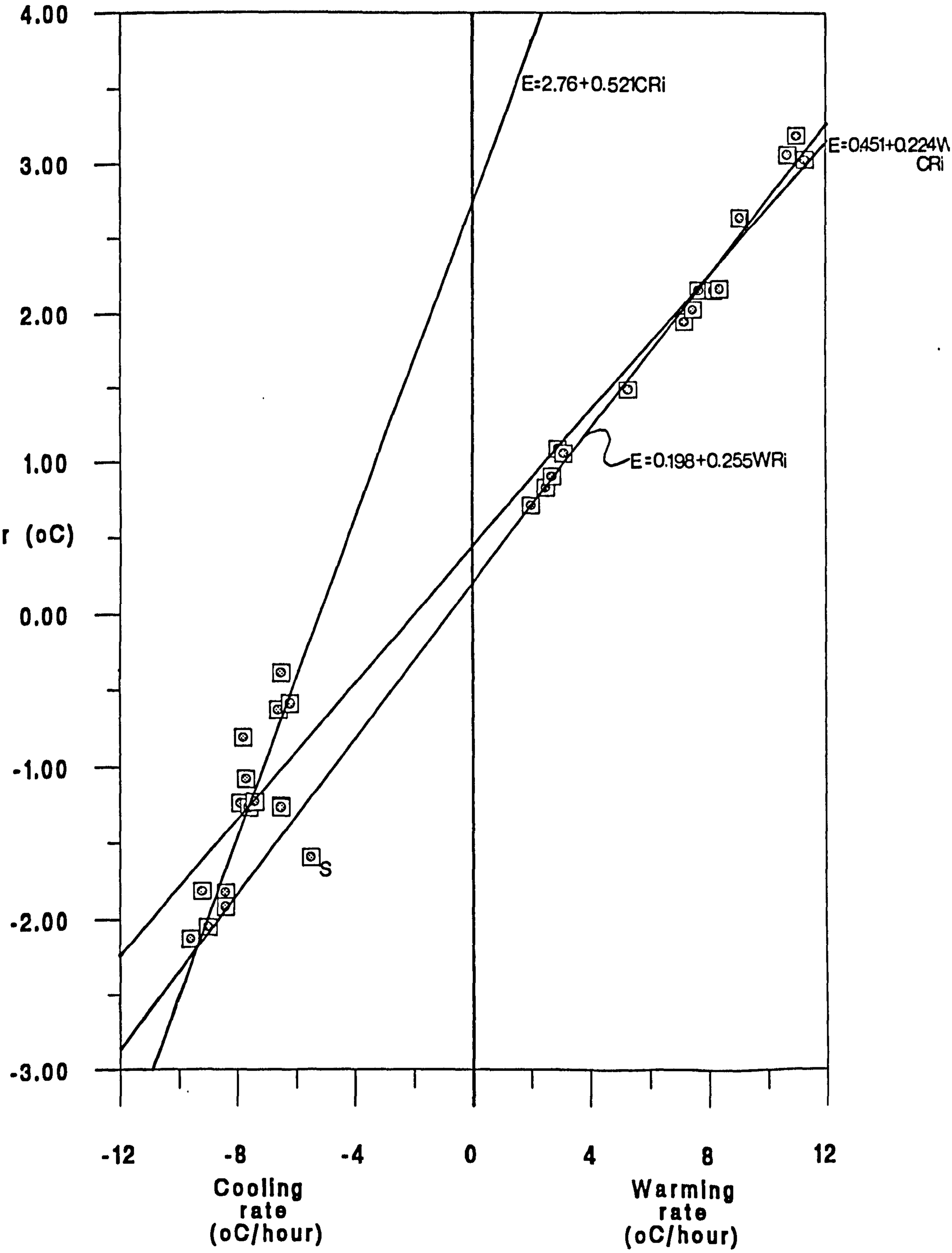


Figure 4.13: Results of KT-17 Laboratory Test 1

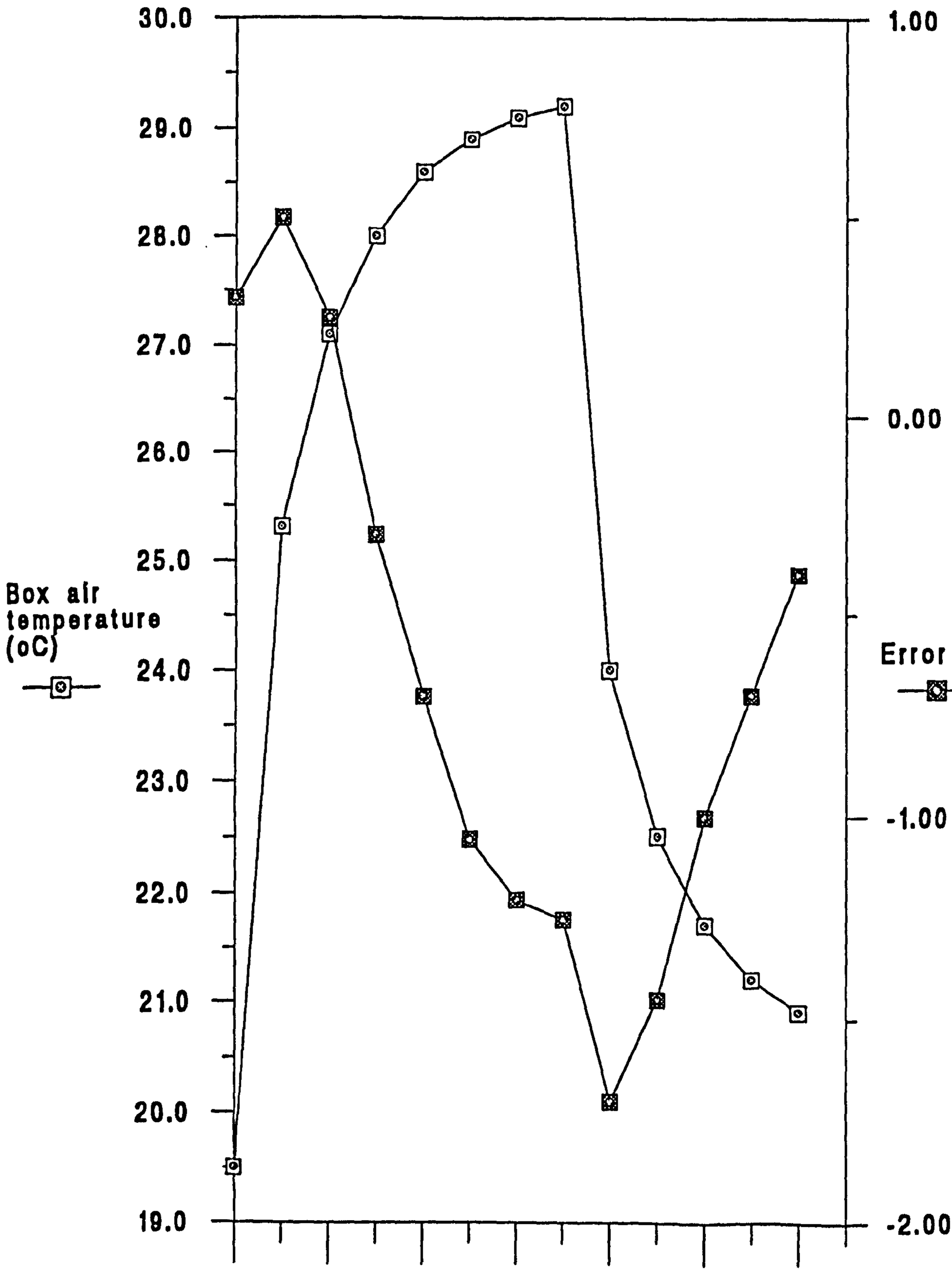
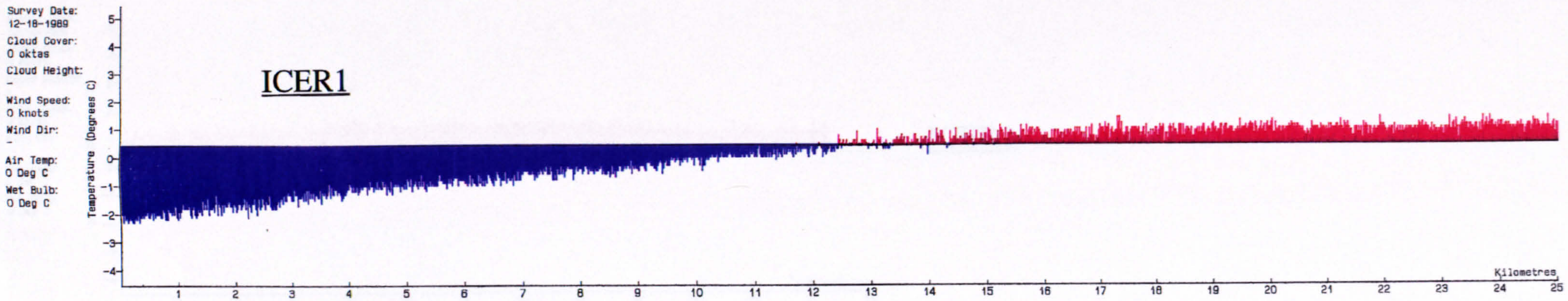


Figure 4.14: Thermal Fingerprints of Runs ICER1 and 2 (continued overleaf)



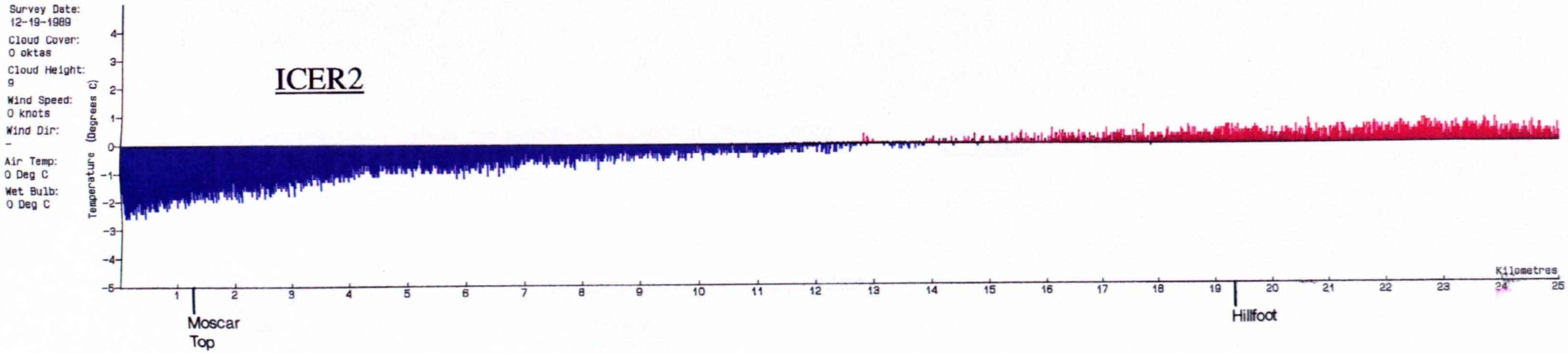
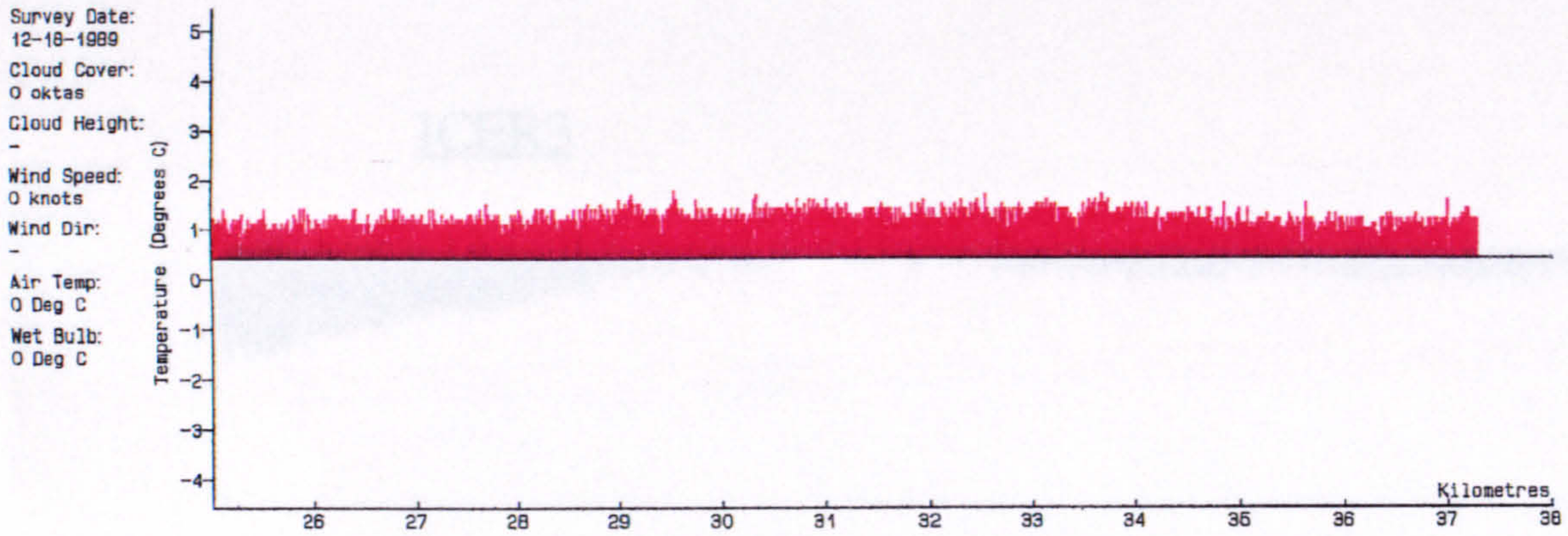
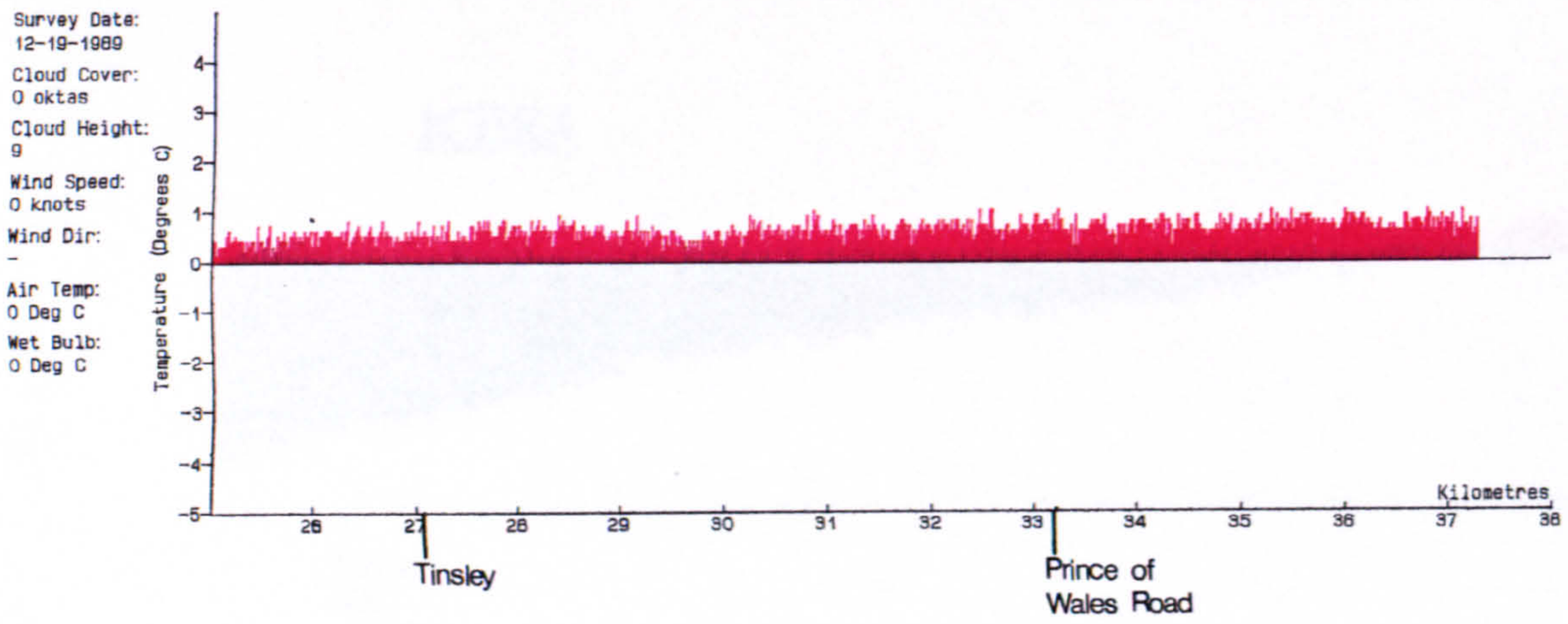


Figure 4.14: Thermal Fingerprints of Runs ICER1 and 2 (continued)

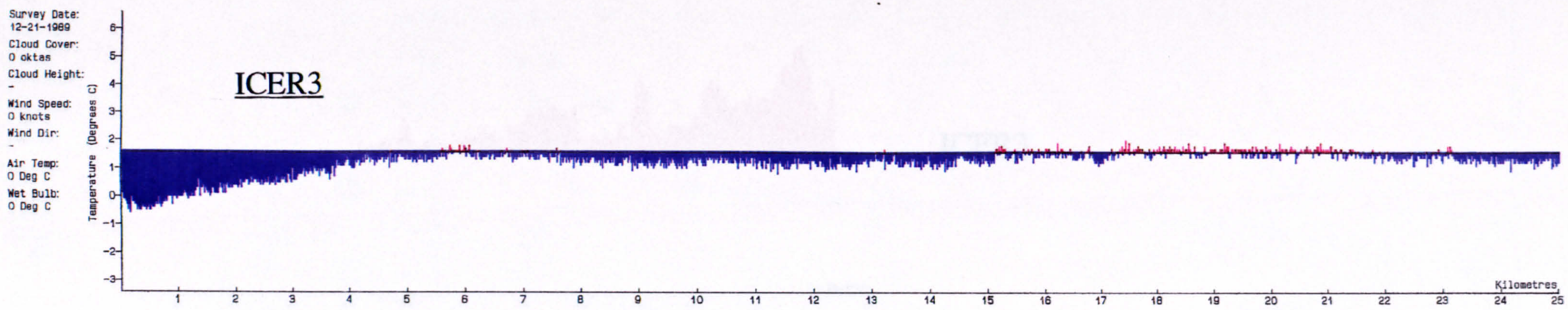


ICER1



ICER2

Figure 4.15: Thermal Fingerprints of Runs ICER3 and 4 (continued overleaf)



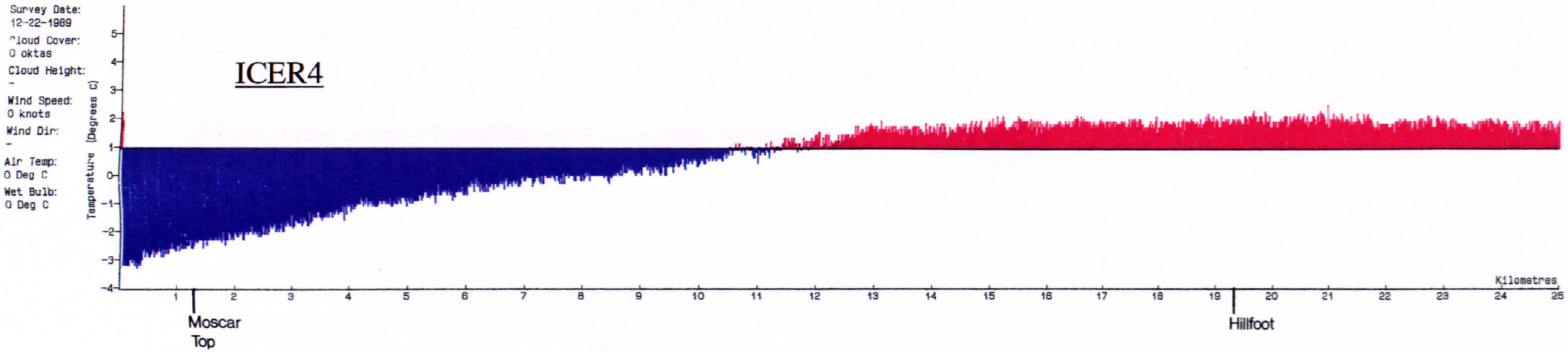
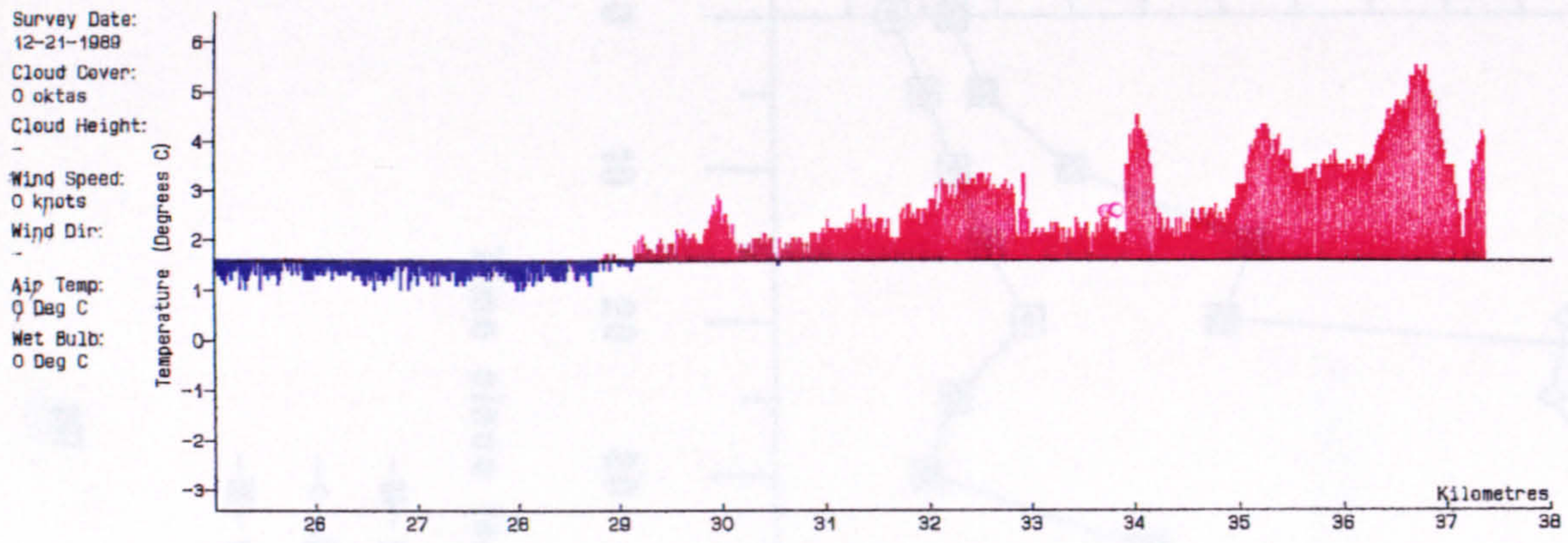
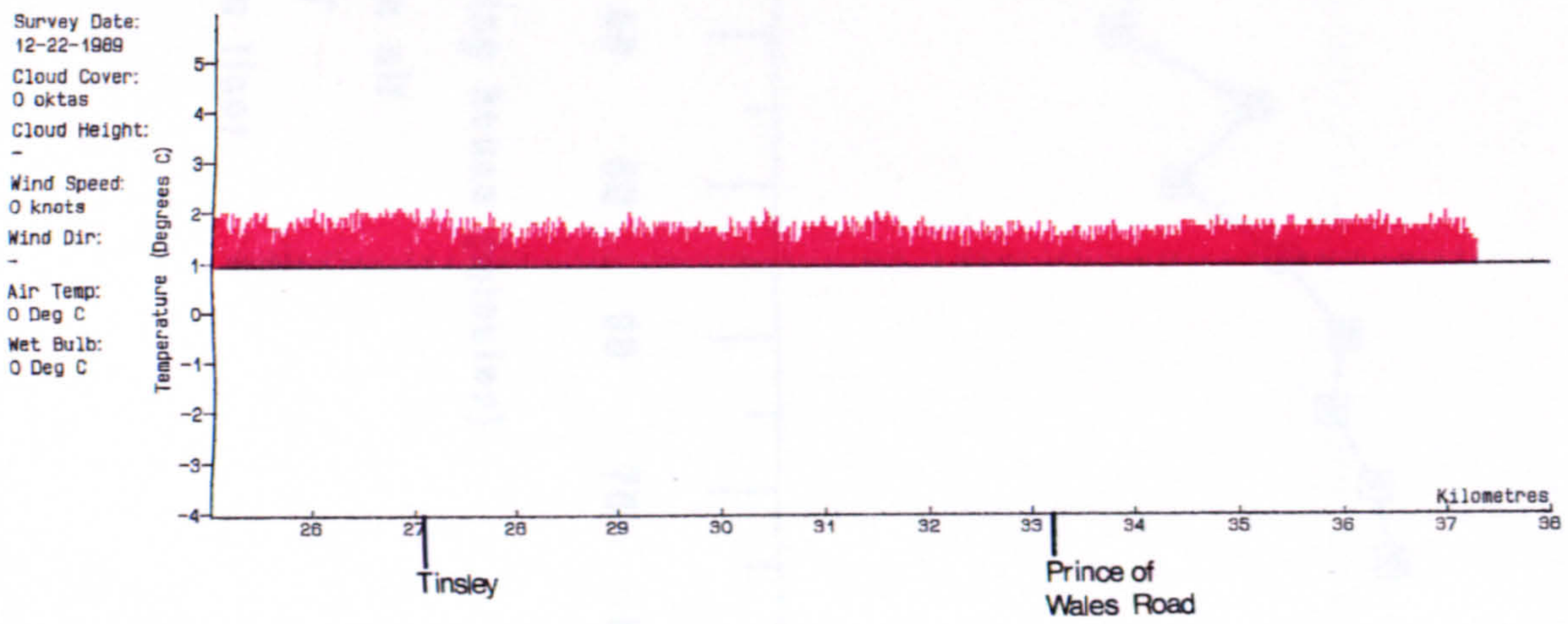


Figure 4.15: Thermal Fingerprints of Runs ICER3 and 4 (continued)



ICER3



ICER4

Figure 4.16: Temperature Variations in Van During ICER Run 1

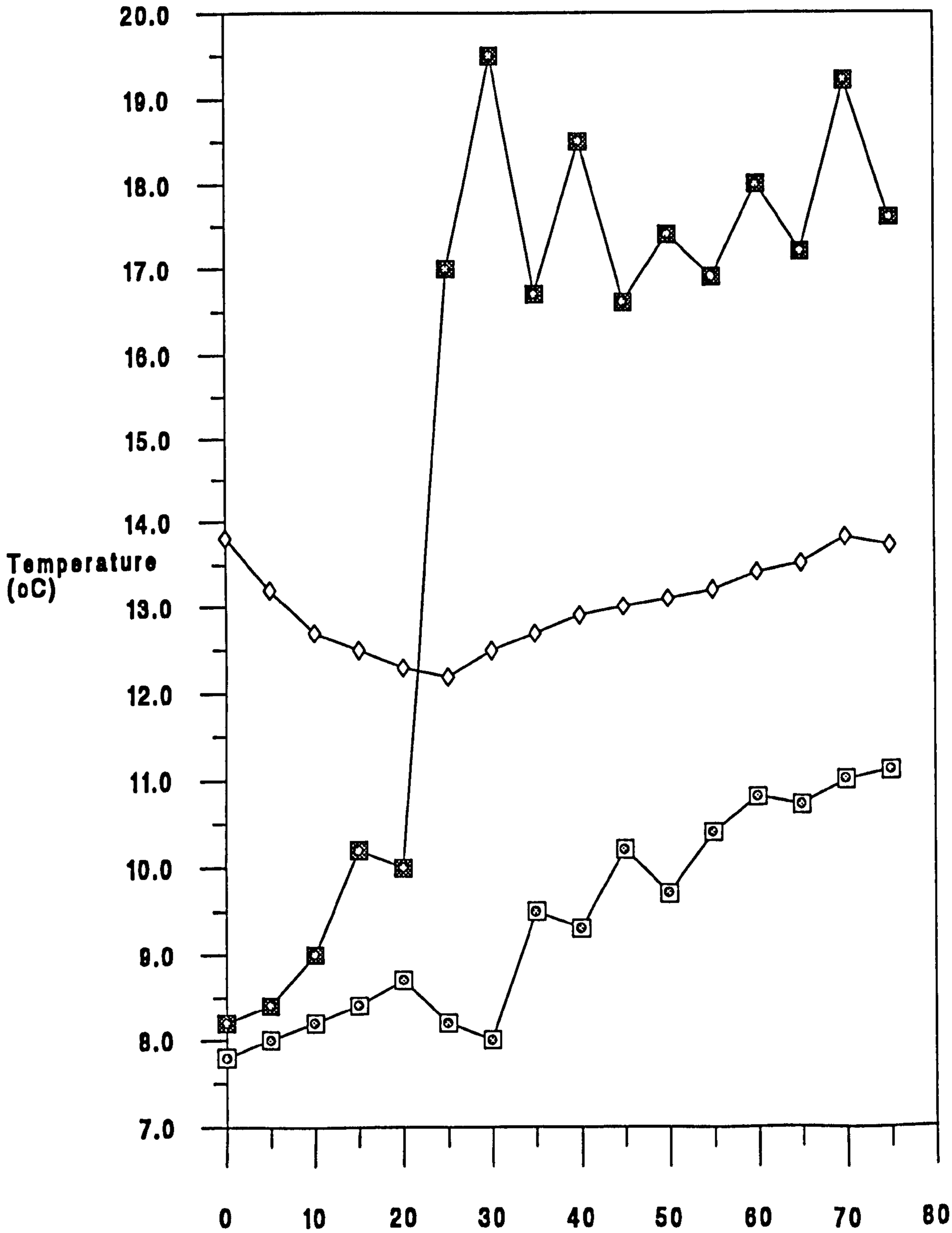
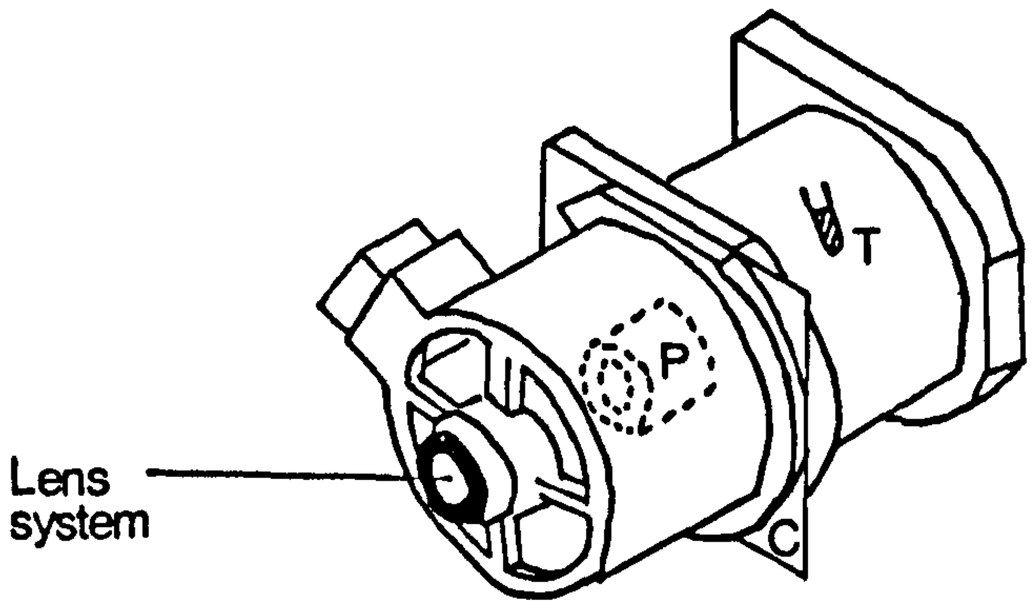


Figure 4.17: Compac 3 IRT Detector Block



KEY

T = thermosensitive resistor

C = chopper

P = pyroelectric cell

SOURCE: LAND Compac 3 Technical Manual

Figure:4.18: The Effect of Moving the IRT From a Warm to a Cold Room ('Bounce')

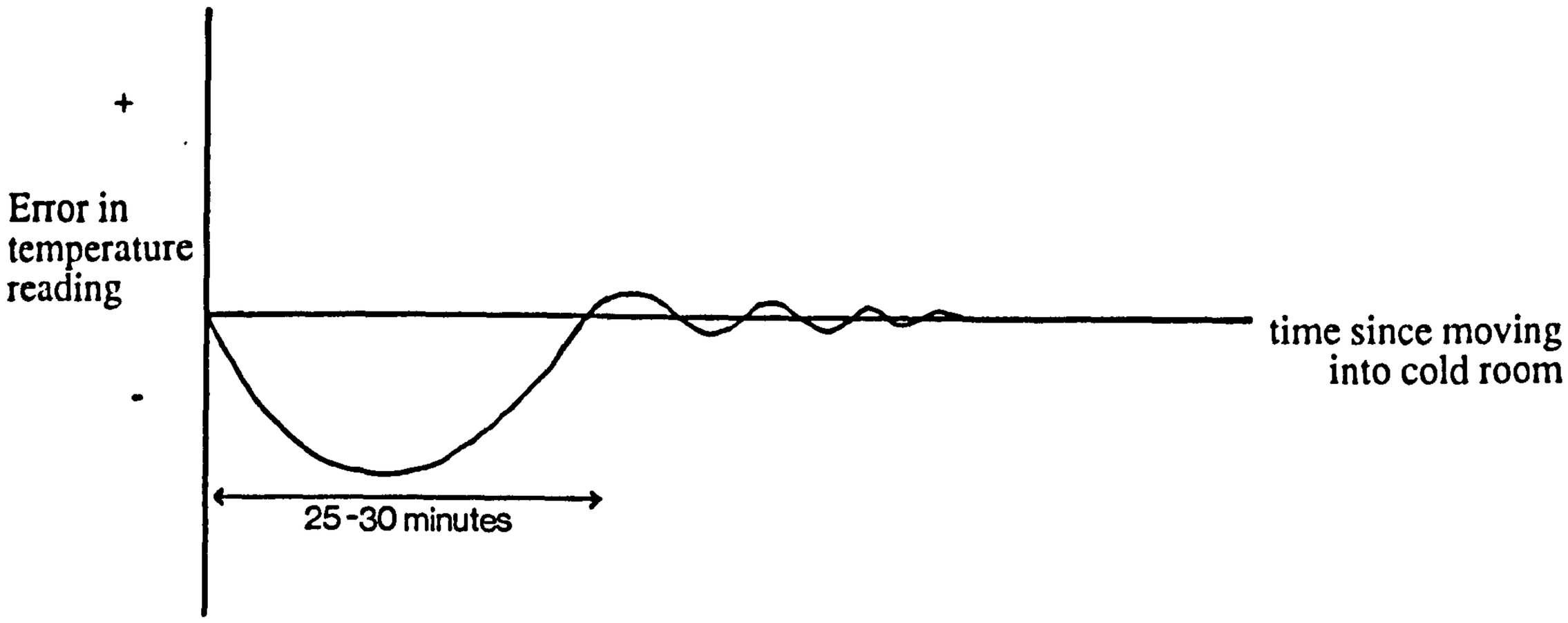


Figure 4.19: Plot of Errors Produced During CTB Test 1

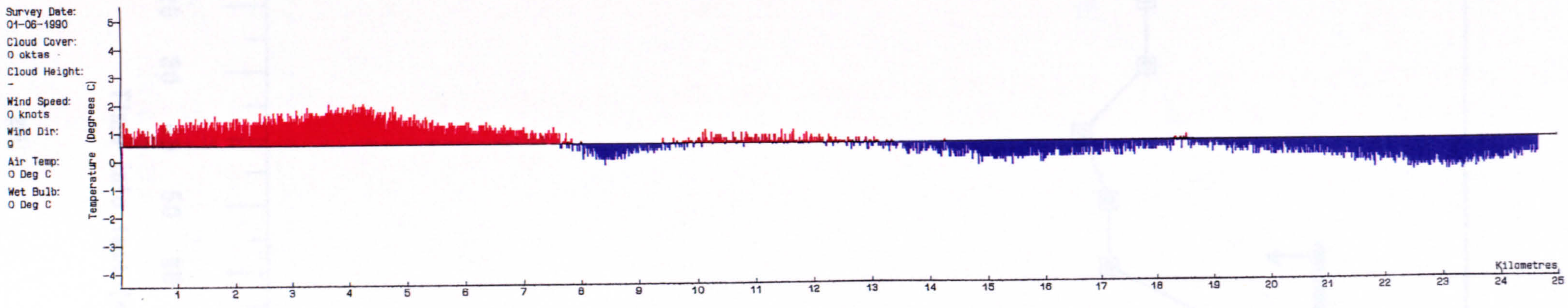


Figure 4.20: Results of CTB Heating Test 17

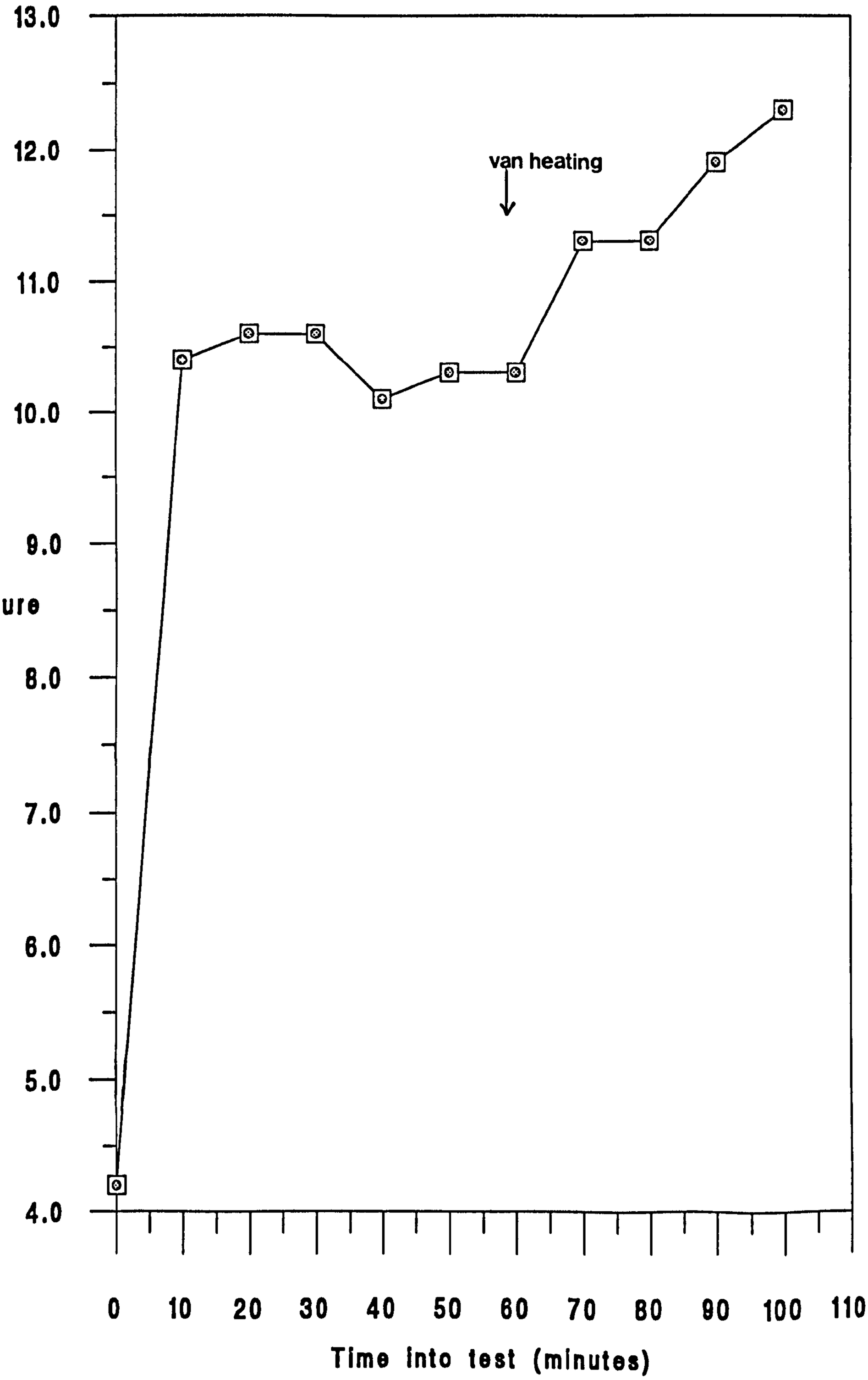


Figure 4.21: Results of CTB Heating Test 19

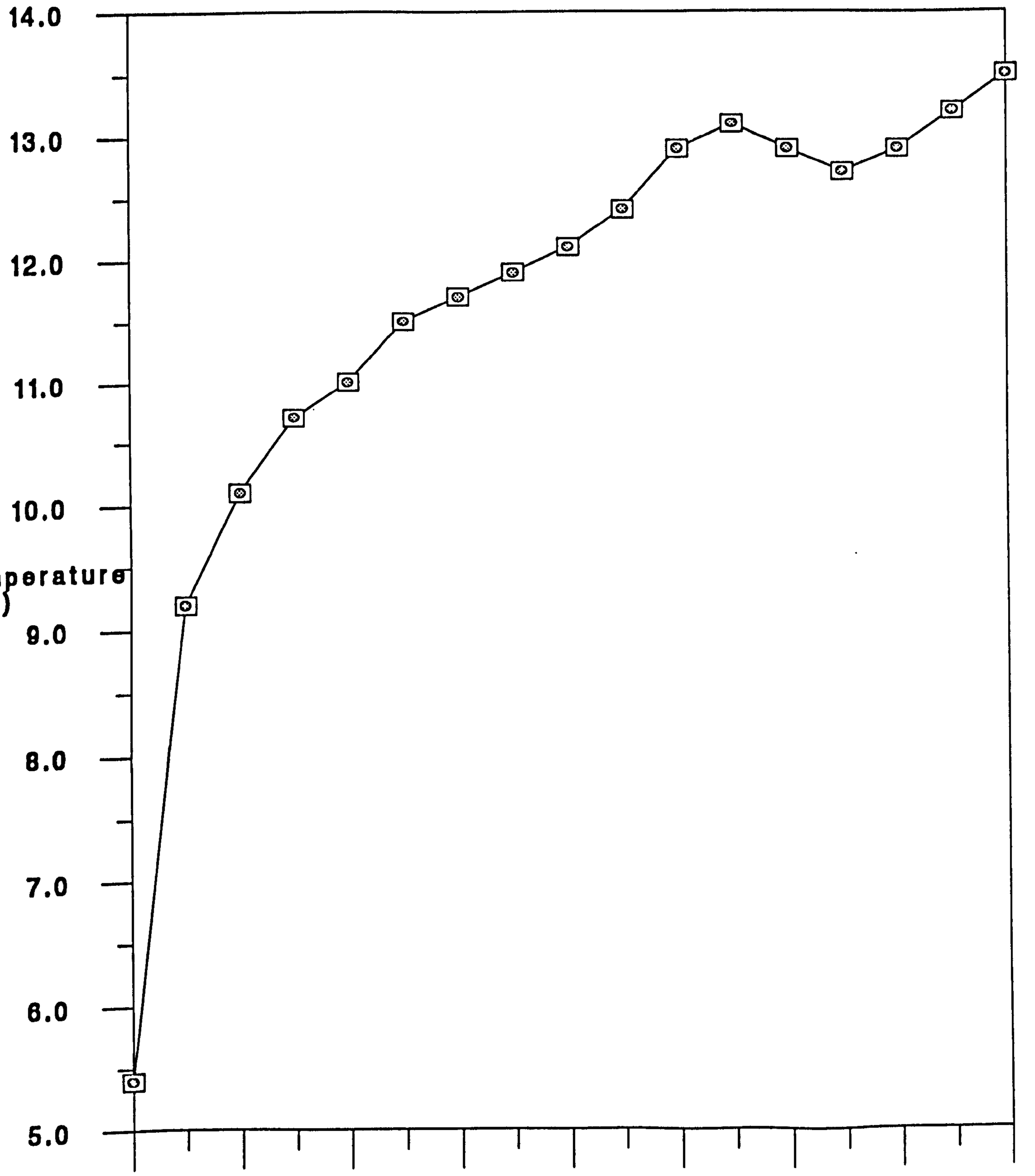


Figure 4.22: Results of CTB Heating Test 20 with Associated Errors in IRT Reading

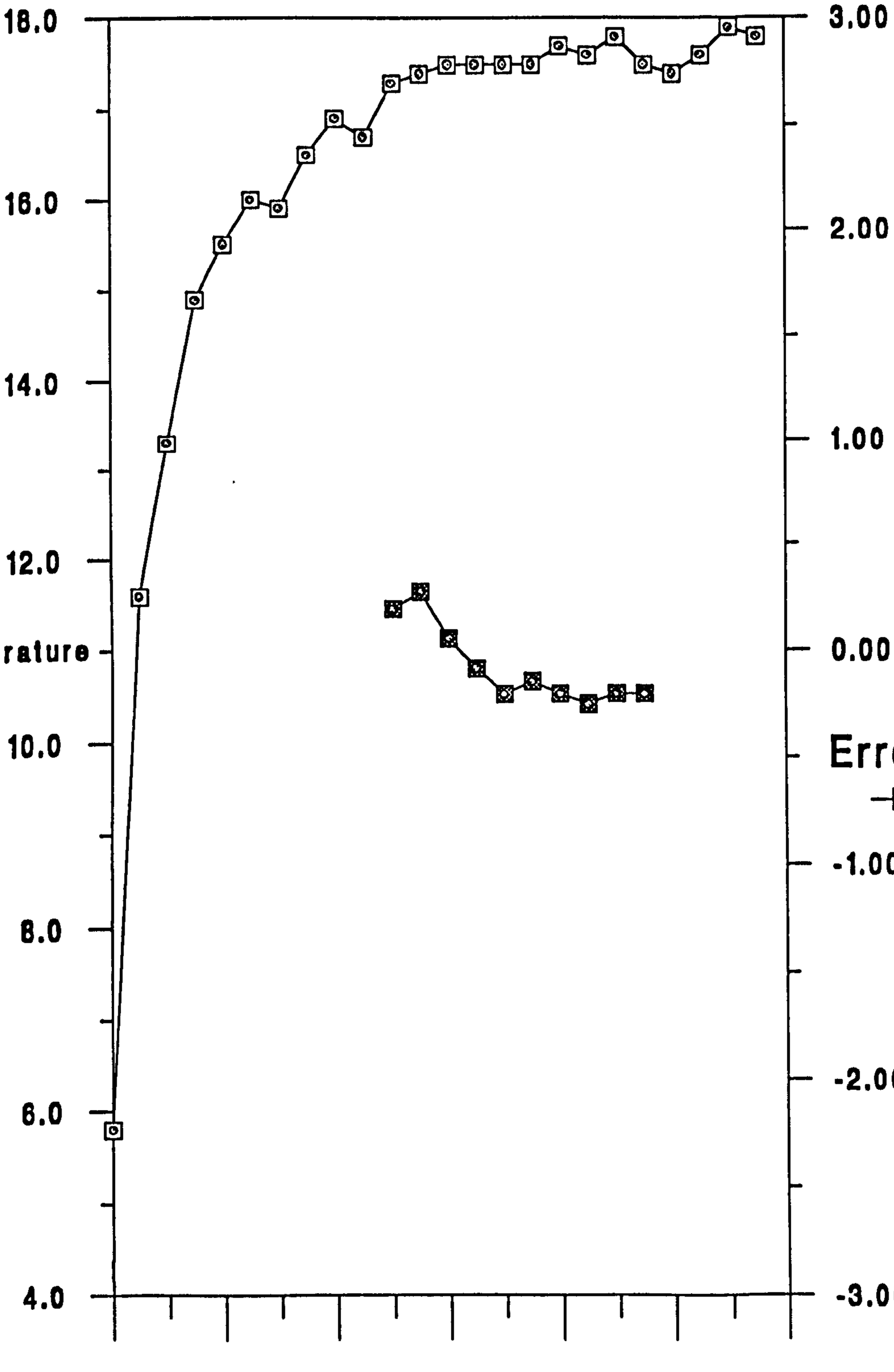
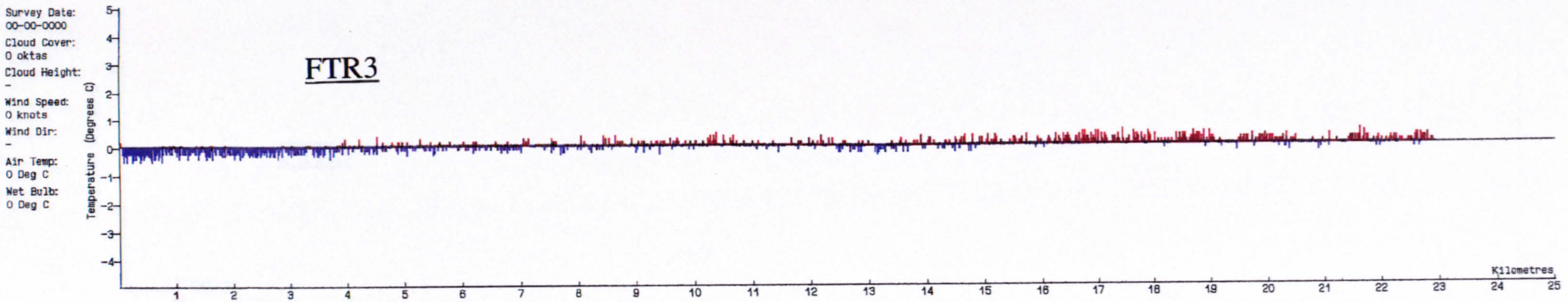


Figure 4.23: Plot of Errors Produced During FTR Tests 3 and 5 (continued overleaf)



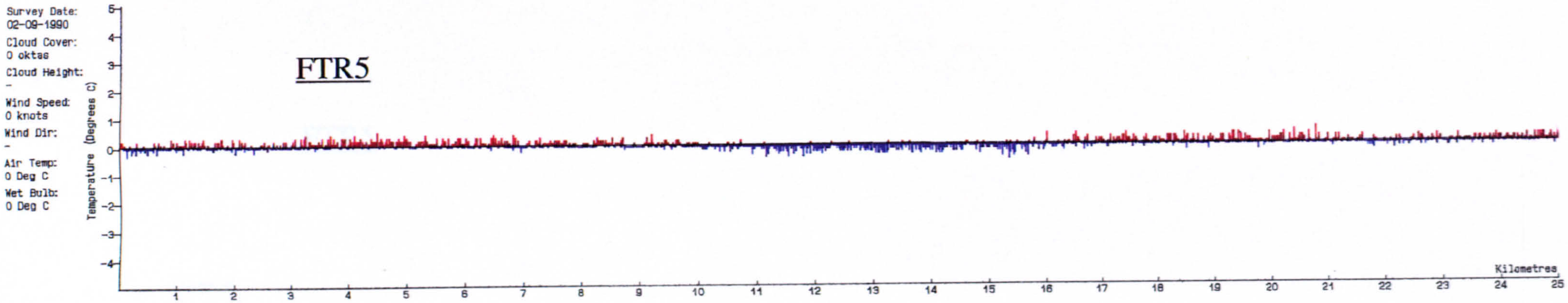
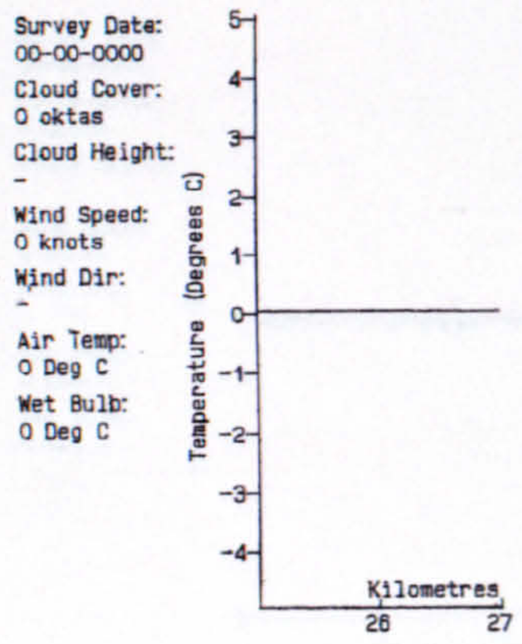
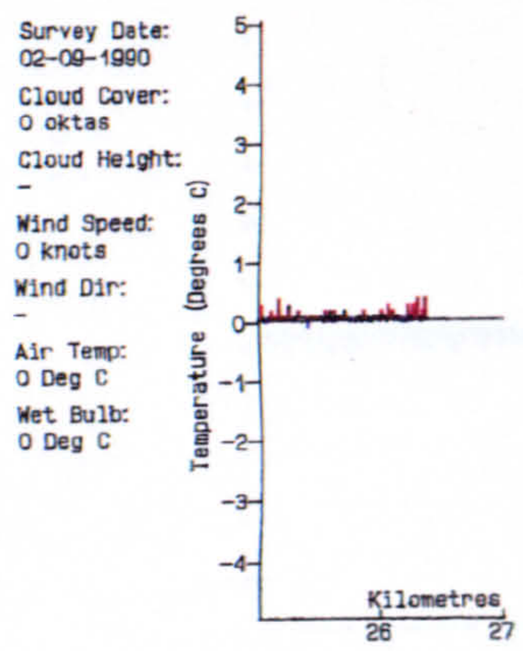


Figure 4.23: Plot of Errors Produced During FTR Tests 3 and 5 (continued)

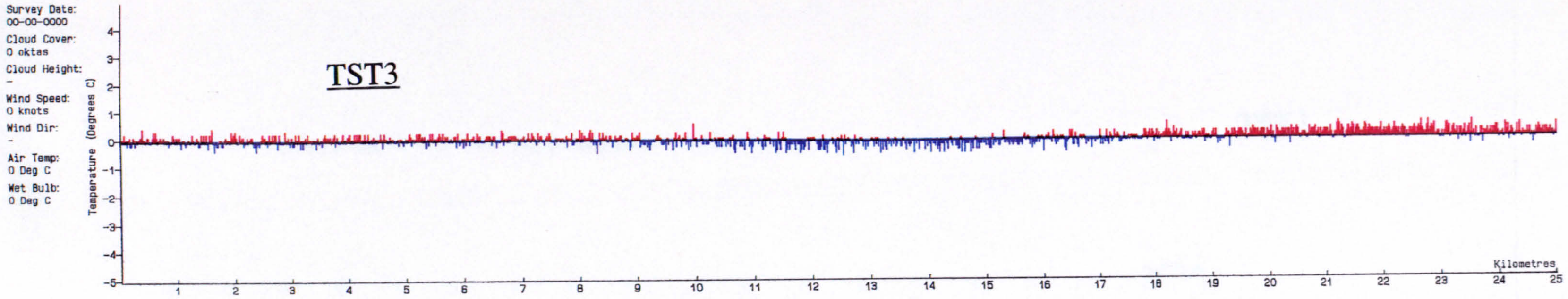


FTR3



FTR5

Figure 4.24: Plot of Errors Produced During TST Tests 3 and 5 (continued overleaf)



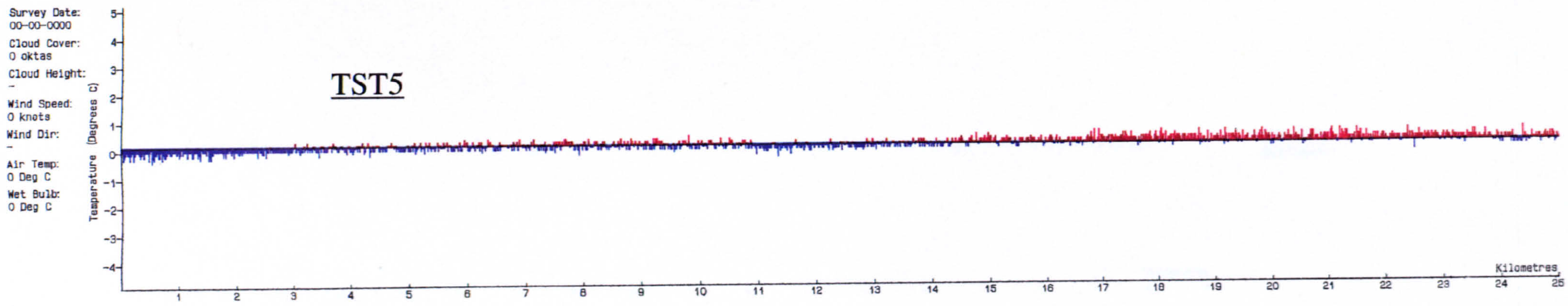
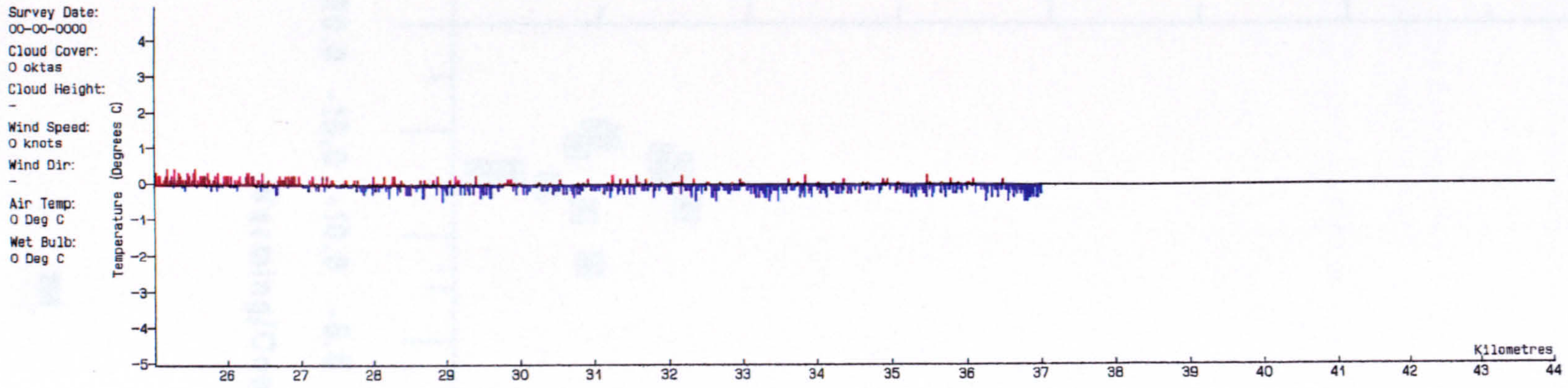
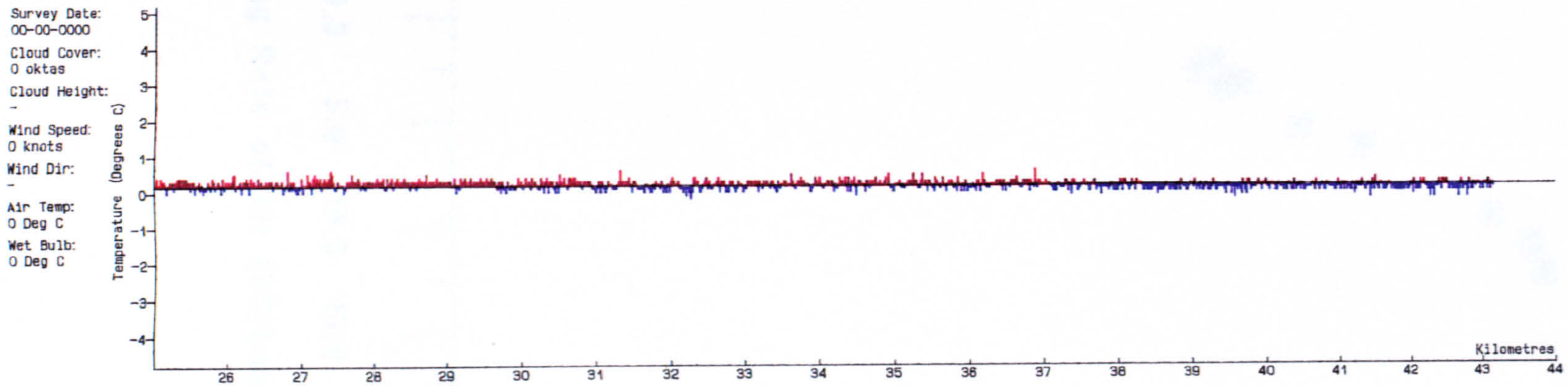


Figure 4.24: Plot of Errors Produced During TST Tests 3 and 5 (continued)



TST3



TST5

Figure 4.25: Plot of Warming/Cooling Rate of Box Air and Warming/Cooling Rate of IRT

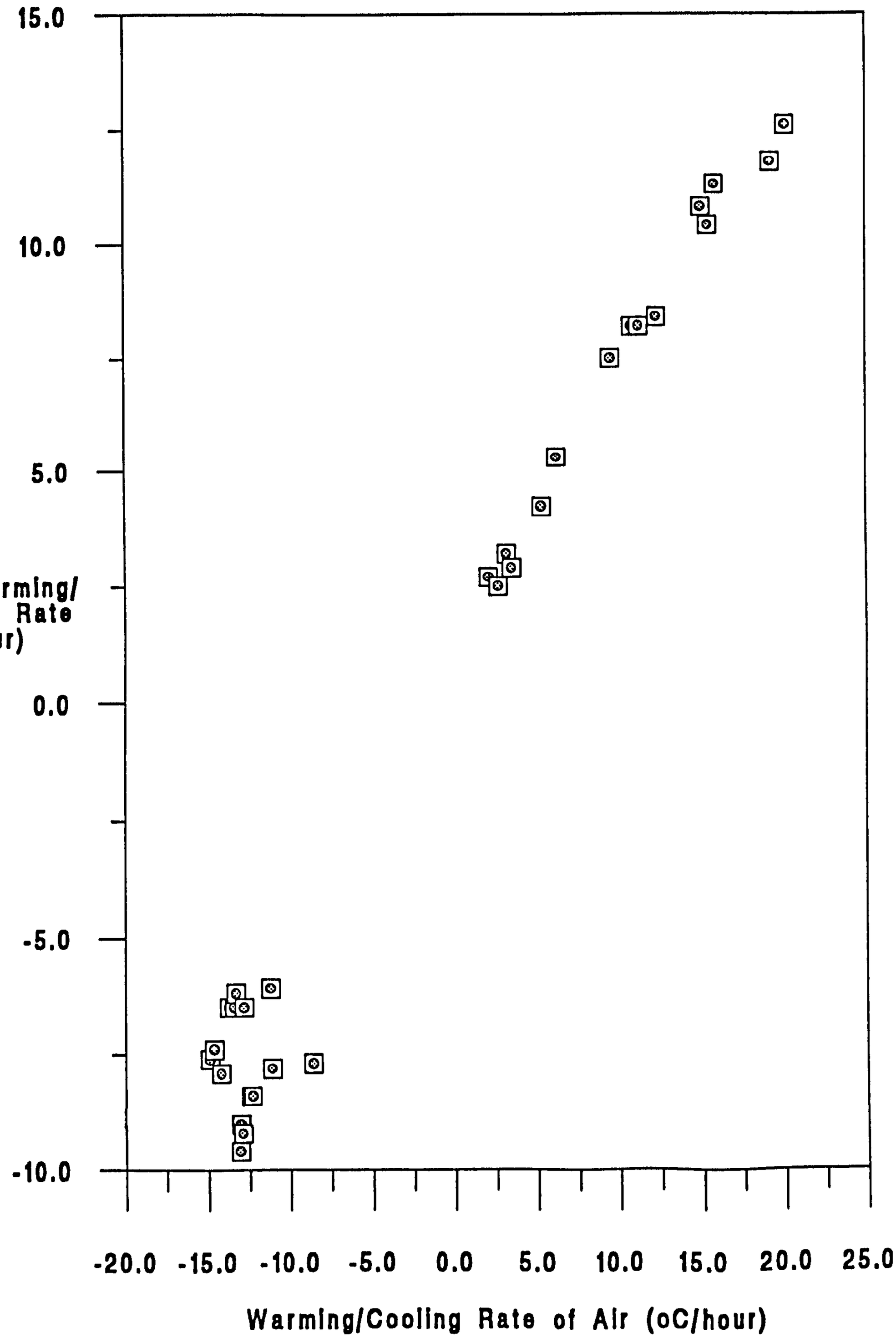


Table 4.1: Errors(^{o}C) of 8-14μm Thermometer Due To Surrounds/Background Being at a Different Temperature to the Thermometer

Temperature of surrounds (^{o}C)	Emissivity of Surrounds								
	0.3			0.6			0.9		
	Target Temperature (^{o}C)								
	50	100	150	50	100	150	50	100	150
0	-38.0	-25.0	-19.0	-10.0	-7.0	-5.0	-1.5	-1.0	-1.0
10	-18.0	-13.0	-10.0	-5.0	-3.5	-3.0	-1.0	-0.5	-0.5
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	+18.0	+13.0	+10.0	+5.0	+3.0	+3.0	+1.0	+0.5	+0.5
40	+35.0	+26.0	+22.0	+11.0	+8.0	+6.0	+2.0	+1.0	+1.0
50	+51.0	+40.0	+33.0	+16.0	+12.0	+10.0	+3.0	+2.0	+1.5

NOTES: 1) Temperature of infra-red thermometer = 20^{o}C.
2) Emissivity set at true value of target.

SOURCE: LAND Infra-red LTD Technical Memo No.94.

Table 4.2: Results of Laboratory Tests Type A

Time into test (mins.)	TEST 1		2		3		4		5	
	Box air temp. (°C)	Error[2]	Box air temp. (°C)	Error	Box air temp. (°C)	Error	Box air temp. (°C)	Error	Box air temp. (°C)	Error
0	21.5	+0.11	21.4	+0.08	21.3	+0.09	20.8	+0.03	21.4	+0.08
10	28.5	+1.42	27.6	+1.52	28.1	+1.57	28.0	+1.32	28.2	+1.89
20	30.3	+2.35	29.4	+2.34	30.3	+2.63	30.3	+2.55	30.5	+2.76
30	31.7	+2.67	30.6	+2.27	31.4	+2.80	31.6	+2.93	31.9	+2.80
40	32.7	+2.53	31.3	+2.14	32.2	+2.41	32.3	+2.47	32.8	+2.54
50	33.3	+2.17	31.7	+1.85	33.0	+2.13	33.1	+2.23	33.3	+1.97
60	33.8	+1.82	32.0	+1.60	33.3	+1.94	33.6	+1.80	33.8	+1.73
70	28.7	+0.57	32.3	+1.20	33.5	+1.49	33.9	+1.37	34.0	+1.39
80	33.0	+0.65	32.4	+1.03	34.0	+1.19	30.3	+0.83	28.8	+0.07
90	34.1	+0.75	32.6	+0.96	28.5	+0.24	32.5	+0.06	33.3	+0.24
100	28.7	+0.24	32.7	+0.81	33.2	+0.14	34.0	+0.75	34.6	+1.29
110[1]	33.3	+0.35	32.8	+0.53	33.6	+0.58	34.1	+0.86	30.7	-0.49
120	27.4	-0.76	25.9	-1.06	27.3	-0.64	27.5	-0.83	26.6	-1.39
130	26.0	-1.56	24.4	-1.62	25.5	-1.46	25.7	-1.51	25.2	-1.75
140	24.9	-1.50	23.8	-1.33	24.5	-1.46	24.8	-1.54	24.4	-1.46
150	24.4	-1.23	23.4	-0.94	23.9	-1.37	24.2	-1.19	23.9	-1.24

NOTES: 1) Reading taken and then bulb turned off.
2) Error is difference from 0.0°C (average of ten readings).

Table 4.3: Results of Laboratory Tests Type B

Time into test (mins.)	TEST 1 Box temp. (°C)	1 Error[2]	2 Box temp. (°C)	2 Error	3 Box temp. (°C)	3 Error	4 Box temp. (°C)	4 Error	5 Box temp. (°C)	5 Error
0	21.1	-0.03	21.4	0.00	20.4	+0.05	21.2	-0.02	21.2	+0.02
10	28.4	+1.00	28.3	+0.85	29.3	+1.57	28.9	+1.24	28.6	+1.06
20	30.7	+2.32	31.4	+2.10	31.4	+2.96	31.3	+2.67	31.2	+2.69
30	32.2	+3.22	32.4	+2.86	32.8	+4.06	32.9	+3.64	32.7	+3.64
40	33.1	+3.30	33.2	+3.09	33.8	+3.87	34.0	+4.02	34.0	+3.94
50	33.9	+3.21	33.9	+3.00	30.2	+3.50	31.0	+3.73	34.4	+3.80
60	30.1	+2.74	29.4	+2.40	33.0	+2.26	32.7	+2.37	31.3	+2.53
70	32.8	+1.67	33.4	+1.25	34.6	+2.24	34.7	+2.35	34.4	+2.33
80	34.2	+1.56	34.3	+1.66	31.8	+1.59	28.7	+1.76	30.1	+2.31
90	29.9	+1.09	30.9	+0.88	34.3	+1.52	34.1	+1.42	33.6	+1.72
100	33.7	+0.86	33.9	+0.69	28.9	+1.53	30.7	+1.66	34.0	+1.94
110[1]	31.8	+1.29	30.0	+0.90	34.0	+1.16	33.2	+1.15	31.5	+1.22
120	27.1	+0.04	26.9	-0.25	27.8	+0.85	27.8	+0.70	27.4	+0.47
130	25.8	-0.70	25.6	-1.20	26.3	-0.36	26.2	-0.28	26.0	-0.27
140	25.0	-1.20	24.8	-1.52	25.4	-0.97	25.4	-0.80	25.2	-0.68
150	24.4	-1.39	24.3	-1.34	24.9	-1.07	24.4	-0.80	24.7	-0.81

NOTES: 1) Reading taken then bulb turned off.
2) Difference from 0.0°C (average of ten readings)

Table 4.4 Results of Laboratory Tests Type C

Time into test (mins.)	TEST 1		2		3		4		5	
	Box temp. (°C)	Error[2]	Box temp. (°C)	Error	Box temp. (°C)	Error	Box temp. (°C)	Error	Box temp. (°C)	Error
0	20.5	+0.28	19.5	+0.29	19.5	+0.52	19.8	+0.57	20.6	+0.55
10	22.1	+0.99	22.8	+0.69	21.4	+0.55	21.5	+0.94	21.2	+0.56
20	22.4	+1.20	23.6	+1.39	22.6	+1.02	23.1	+1.30	22.4	+0.84
30	22.7	+1.18	24.2	+1.41	23.0	+1.33	23.4	+1.68	22.5	+1.11
40	23.2	+1.10	24.7	+1.37	23.4	+1.29	24.0	+1.51	22.8	+1.12
50	23.4	+0.96	25.1	+1.26	23.7	+1.08	24.4	+1.34	23.2	+0.96
60	23.5	+0.88	25.7	+1.18	23.7	+0.86	24.7	+1.16	23.3	+0.83
70	24.1	+0.86	25.7	+0.99	23.9	+0.64	24.7	+1.01	23.4	+0.64
80	24.2	+0.74	25.6	+0.97	24.2	+0.73	24.8	+0.85	23.6	+0.50
90	24.2	+0.66	25.8	+0.81	24.0	+0.49	25.0	+0.66	23.5	+0.47
100	24.4	+0.75	25.9	+0.84	24.1	+0.53	25.2	+0.71	23.6	+0.38
110[1]	24.4	+0.68	26.0	+0.68	24.5	+0.62	25.1	+0.72	23.6	+0.39
120	20.4	-0.78	21.5	-0.77	19.7	-1.34	20.9	-0.81	19.0	-1.39
130	18.2	-1.94	19.3	-2.10	17.8	-2.17	18.7	-2.22	17.0	-2.36
140	16.9	-2.36	18.5	-2.24	16.6	-2.46	17.5	-2.39	15.7	-2.54
150	16.2	-2.24	17.4	-2.15	15.9	-2.22	16.9	-2.26	14.9	-2.24

NOTES: 1) Reading taken then bulb turned off.
2) Difference from 0.0°C (average of ten readings)

Table 4.5: Warming/Cooling Rates of Box Air With Associated Error

Test	Warming rate (°C/hour)	Error[1]	Cooling Rate (°C/hour)	Error[1]
A1	+12.3	+2.16	-13.4	-1.26
A2	+10.8	+2.15	-12.8	-1.27
A3	+6.2	+1.48	-14.2	-1.24
A4	+9.5	+2.02	-14.6	-1.23
A5	+11.2	+2.10	-14.9	-1.27
B1	+15.4	+2.61	-11.1	-0.81
B2	+15.0	+2.38	-11.5	-0.68
B3	+20.1	+3:12	-13.7	-0.39
B4	+19.2	+2.89	-13.3	-0.30
B5	+15.8	+3.03	-11.2	-0.01
C1	+2.1	+0.91	-12.4	-1.83
C2	+3.5	+1.05	-12.9	-1.82
C3	+2.7	+0.83	-13.0	-2.05
C4	+3.2	+1.12	-12.3	-1.92
C5	+2.0	+0.71	-13.1	-2.13
SUBSID.	-	-	-	-

NOTE: 1) Difference from 0.0°C

Table 4.6: Warming/Cooling Rates of IRT With Associated Error

Test	Warming rate (°C/hour)	Error[1]	Cooling Rate (°C/hour)	Error[1]
A1	+8.4	+2.16	-6.5	-1.26
A2	+5.3	+1.48	-7.9	-1.24
A3	+7.5	+2.02	-7.4	-1.23
A4	+7.2	+1.94	-7.6	-1.27
A5	+8.2	+2.15	-6.5	-1.27
B1	+9.1	+2.63	-7.8	-0.81
B2	+7.7	+2.15	-7.7	-1.08
B3	+11.0	+3.19	-6.5	-0.39
B4	+10.7	+3.06	-6.6	-0.63
B5	+11.3	+3.03	-6.2	-0.59
C1	+2.7	+0.90	-8.4	-1.83
C2	+3.1	+1.05	-9.2	-1.82
C3	+2.5	+0.83	-9.0	-2.05
C4	+2.9	+1.08	-8.4	-1.92
C5	+2.0	+0.71	-9.6	-2.13
SUBSID.	-	-	-5.5	-1.60

NOTE: 1) Difference from 0.0°C

Table 4.7: Results of Laboratory Tests on Heimann KT-17

Time into tests (mins.)	TEST 1		2		3		4		5	
	Box temp. (°C)	Error[2]	Box temp. (°C)	Error	Box temp. (°C)	Error	Box temp. (°C)	Error	Box temp. (°C)	Error
0	19.5	+0.30	19.7	+0.10	19.2	+0.10	19.9	-0.05	20.4	+0.25
10	25.3	+0.50	25.6	+0.50	25.1	+0.35	25.8	+0.40	26.5	+0.50
20	27.1	+0.25	27.1	+0.20	27.0	+0.20	27.6	+0.15	28.5	+0.30
30	28.0	-0.30	28.0	-0.30	28.0	-0.40	28.5	-0.25	29.6	-0.20
40	28.6	-0.70	28.5	-0.70	28.4	-0.70	29.1	-0.75	30.3	-0.70
50	28.9	-1.05	28.7	-1.05	28.6	-1.20	29.1	-1.10	30.6	-0.90
60	29.1	-1.20	29.0	-1.10	28.7	-1.35	29.4	-1.15	30.9	-1.15
70[1]	29.2	-1.25	29.0	-1.40	29.1	-1.30	29.5	-1.45	31.0	-1.25
80	24.0	-1.70	23.9	-1.65	23.7	-1.70	24.0	-1.70	25.8	-1.70
90	22.5	-1.45	22.2	-1.65	22.3	-1.50	22.6	-1.40	24.2	-1.45
100	21.7	-1.00	21.4	-0.95	21.6	-0.80	21.7	-1.10	23.3	-1.05
110	21.2	-0.65	21.2	-0.65	21.3	-0.50	21.3	-0.55	22.8	-0.90
120	20.9	-0.35	21.1	-0.35	21.1	-0.45	21.0	-0.65	22.6	-0.55

NOTES: 1) Reading taken then bulb turned off.
2) Difference from 0.0°C (mid-value of range observed over 15 second period).

Table 4.8: Summary of Mapping Winters 1989/90 and 1990/91

Route	Extreme[1]	Intermediate[1]	Damped[1]	Others[1]	Invalid runs[2]
1	20	11	11	58	-
2	7	5	3	8	-
3	6	7	3	7	-
4	5	8	1	12	1 (ST13)
5	6	8	3	10	-
6	5	6	2	6	2 (RNG 5, 10)
7	5	5	2	12	-

NOTES: 1) Classification as in Chapter 3 section 3.3.
2) Runs excluded because change in box temperature during run too large.

Photo 4.1: Temperature Control Box Used In Laboratory Tests

Photo 4.2: Location of IRT and Fans During Laboratory Tests

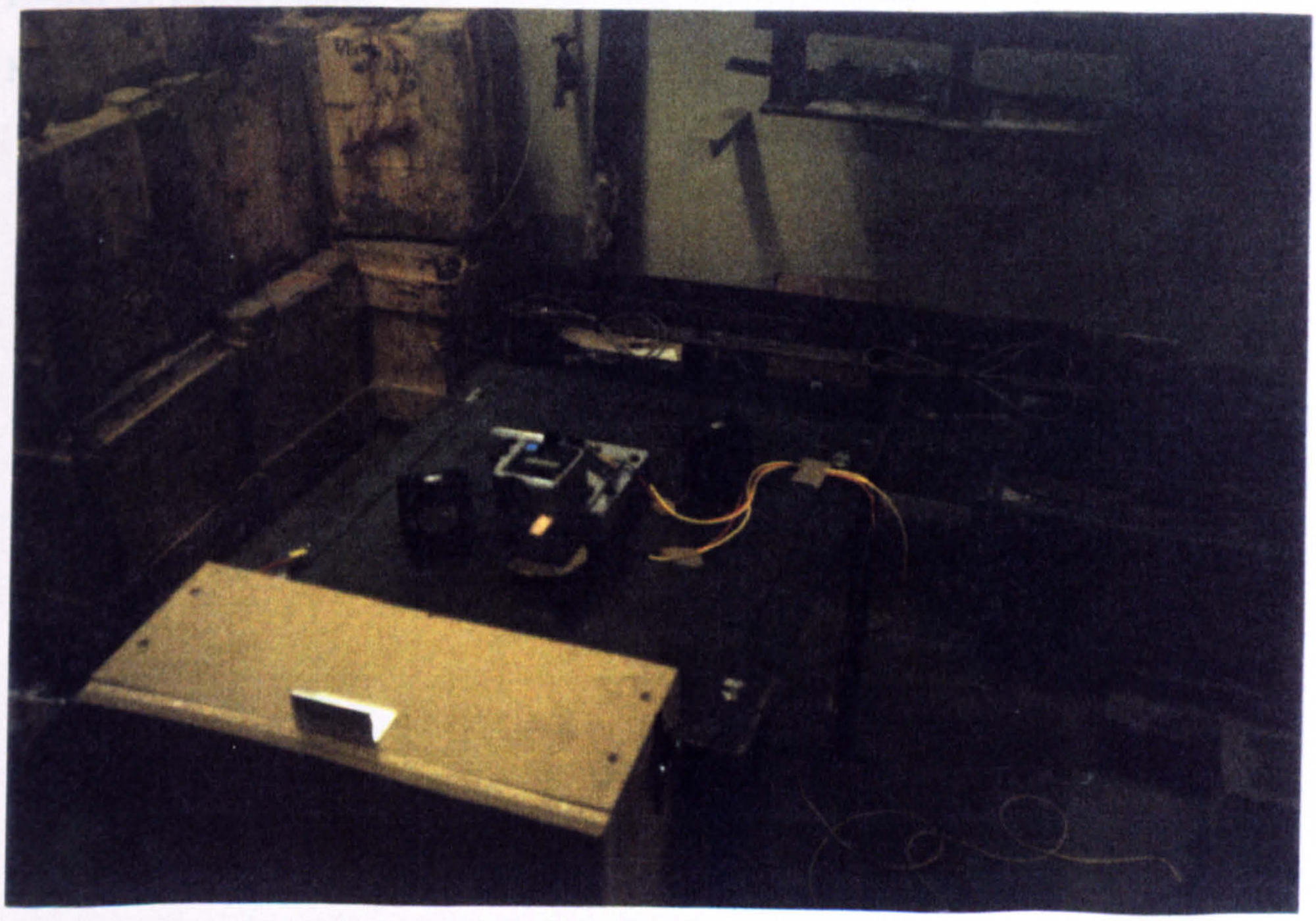
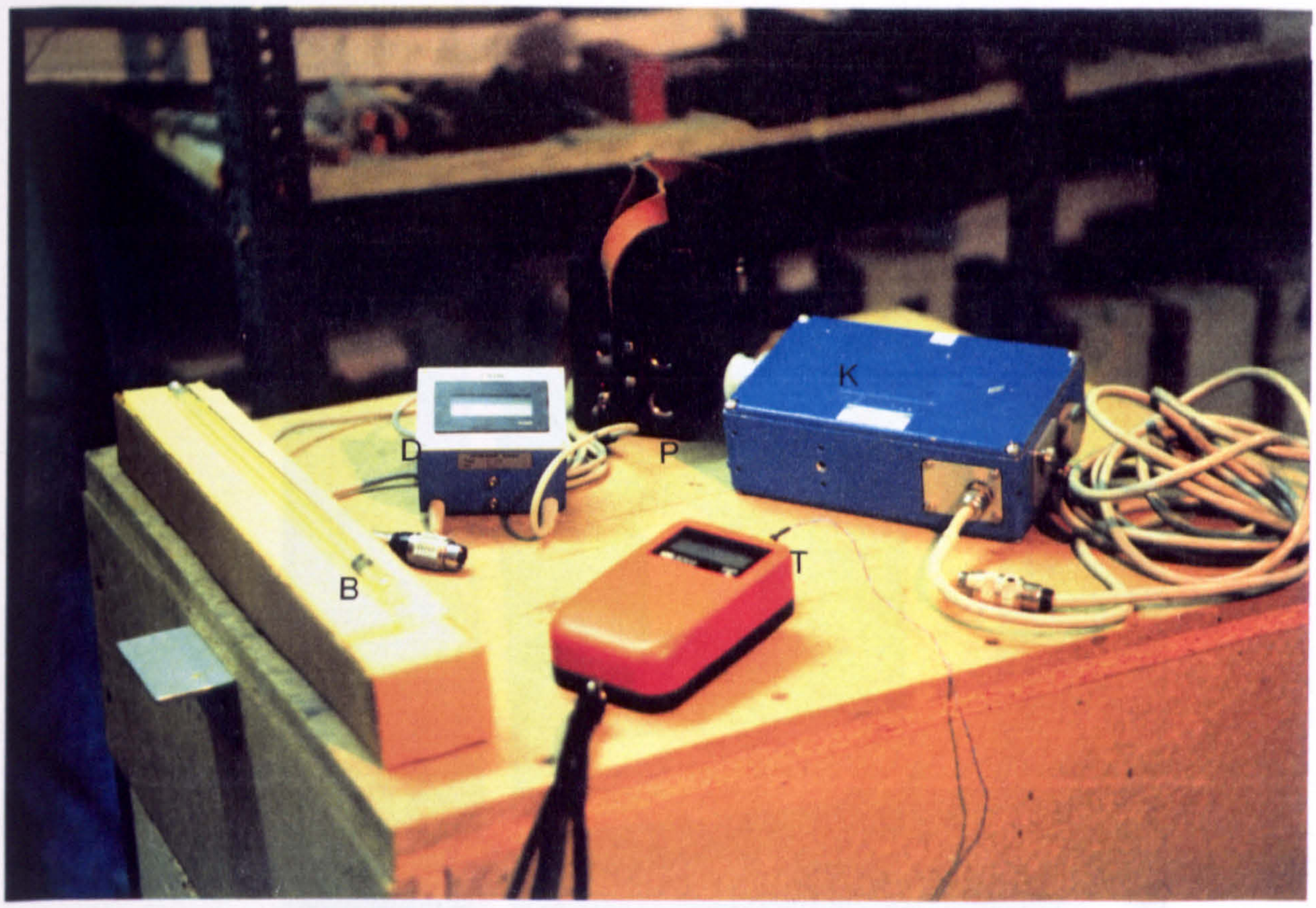


Photo 4.3: Equipment Used In KT-17 Laboratory Tests



B = BSI standard test thermometer

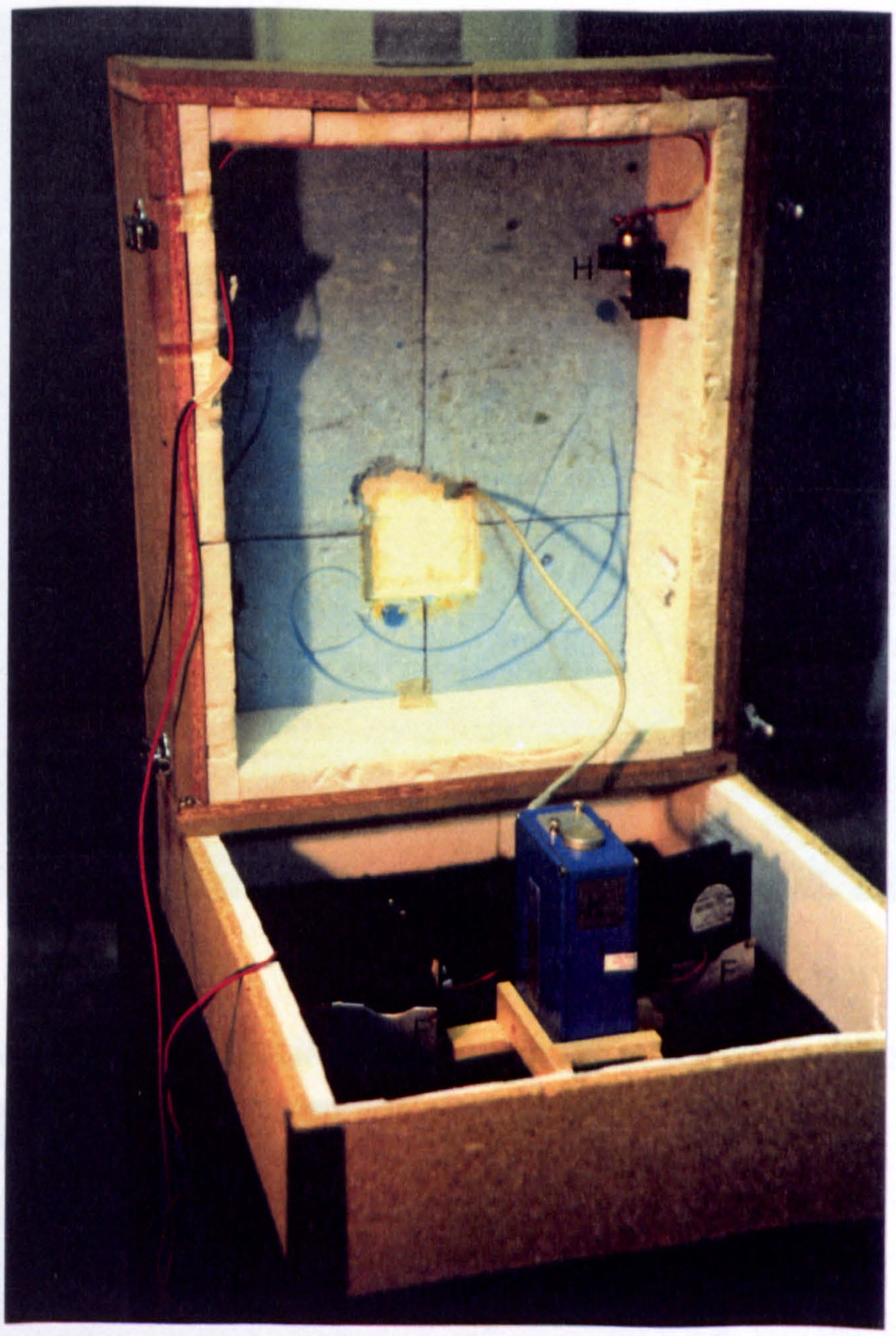
T = thermocouple and display

D = KT-17 display

P = KT-17 power supply

K = KT-17 IRT

Photo 4.4: Temperature Control Box Used in KT-17 Tests



K = KT-17

F = fans

H = heat source

Photo 4.5: Position of Ice Tray Under Van

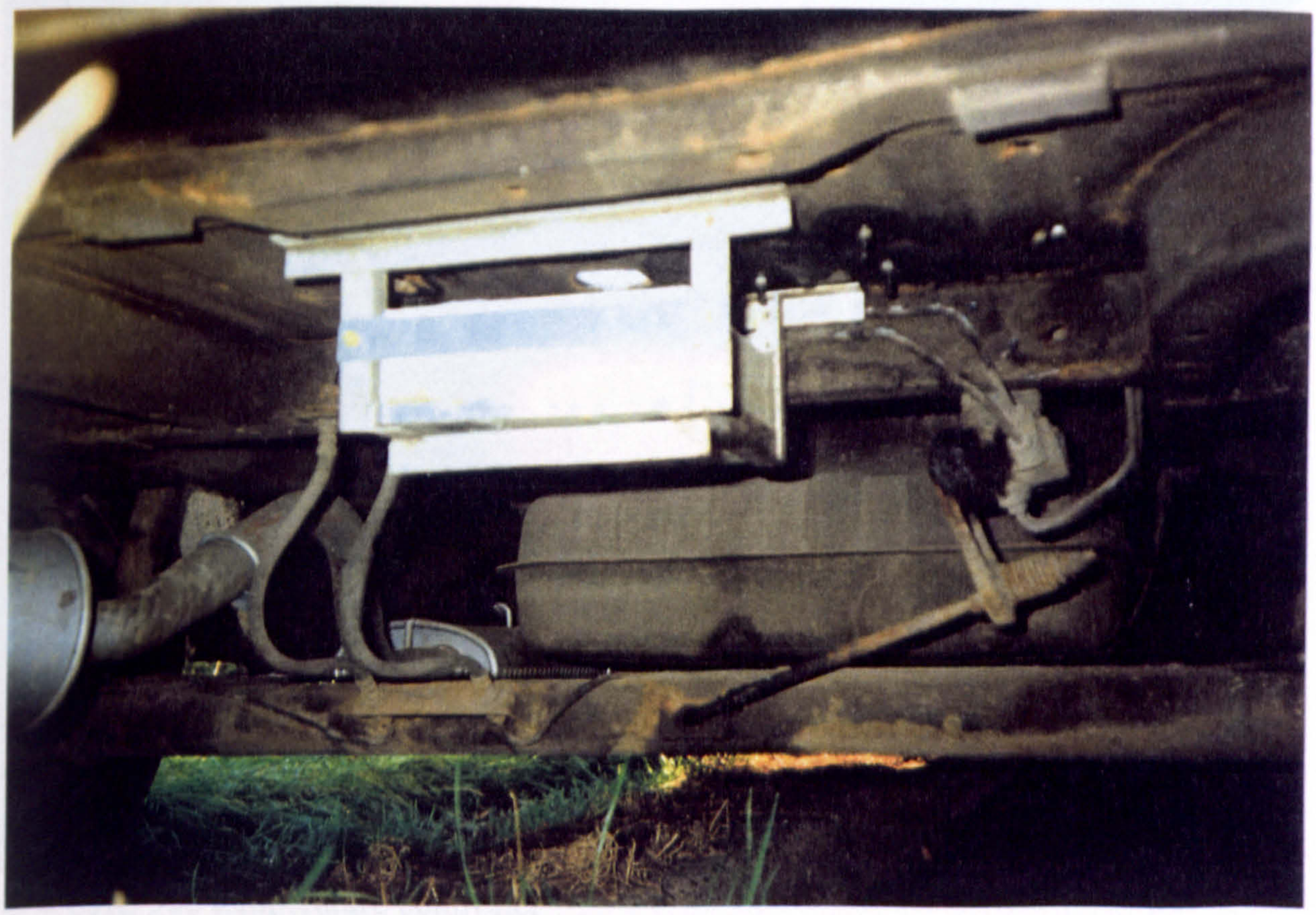


Photo 4.6: Temperature Control Box Used in Van 1989/90 With Insulation

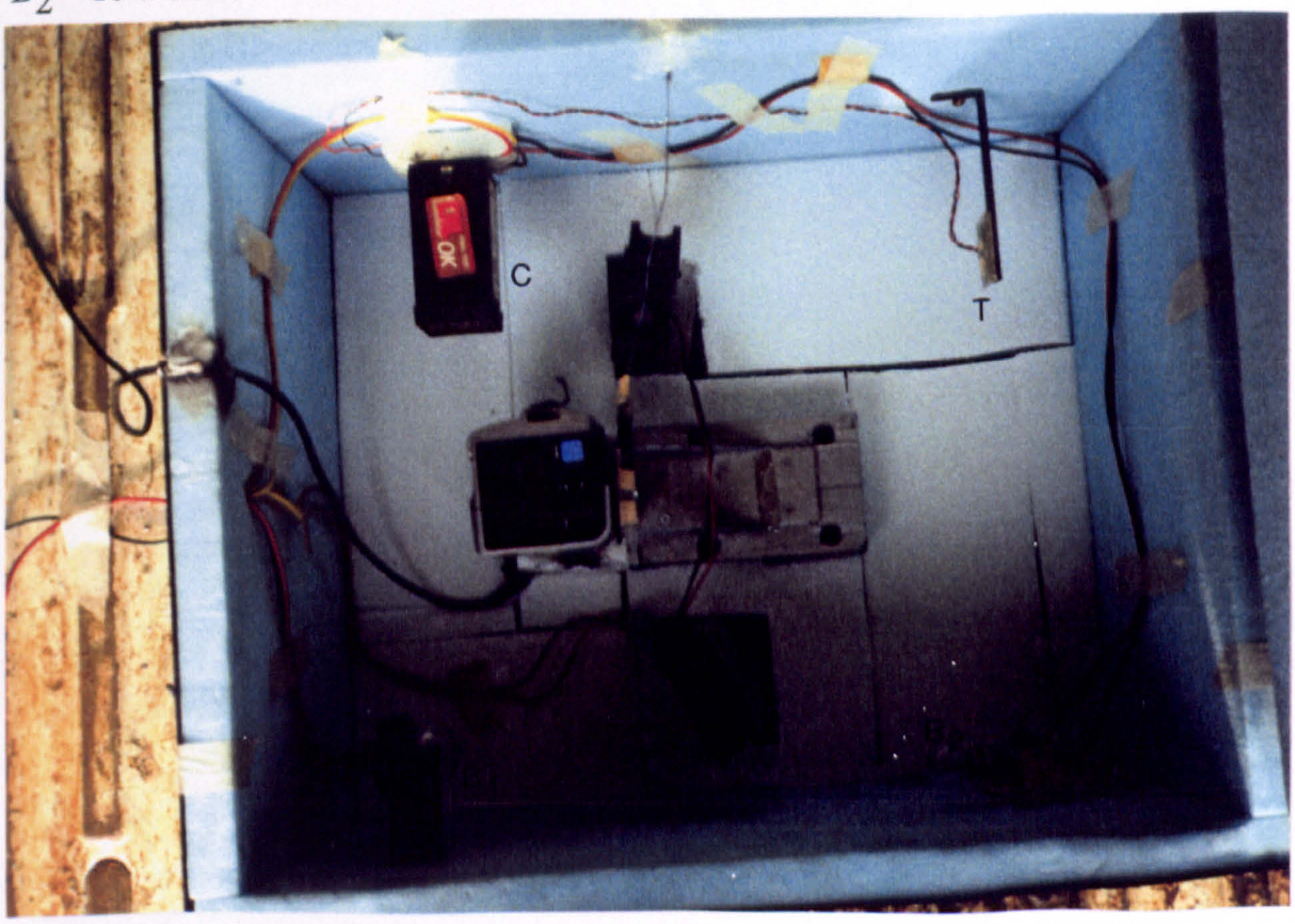
Photo 4.7: Temperature Control Box Used in Van 1990/91

C = CAL 900 temperature controller

T = thermocouple temperature sensor

B_1 = 40 watt bulb

B_2 = 10 watt bulb



CHAPTER 5

Extreme Fingerprints of Route 1 (continued overleaf)

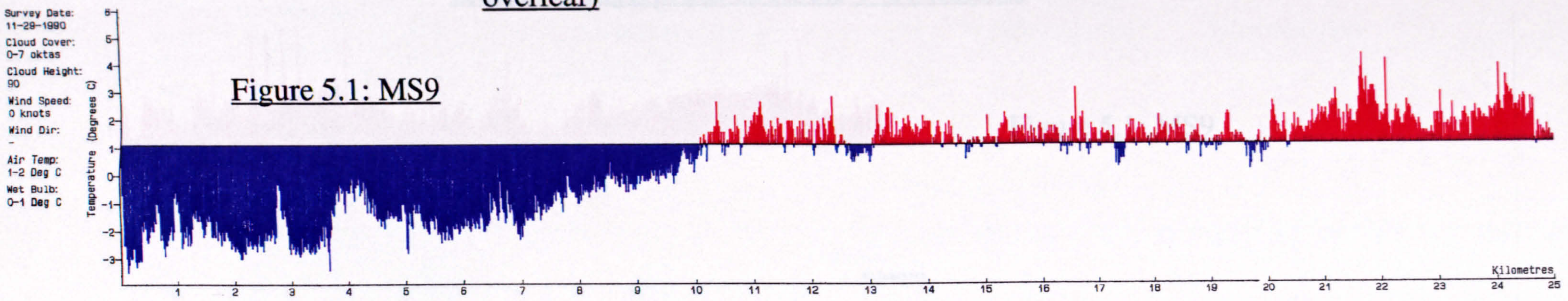


Figure 5.1: MS9

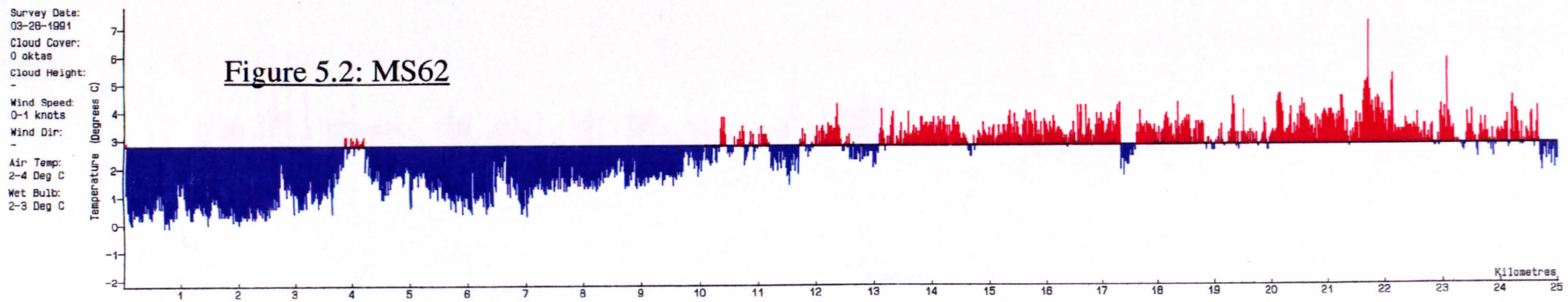


Figure 5.2: MS62

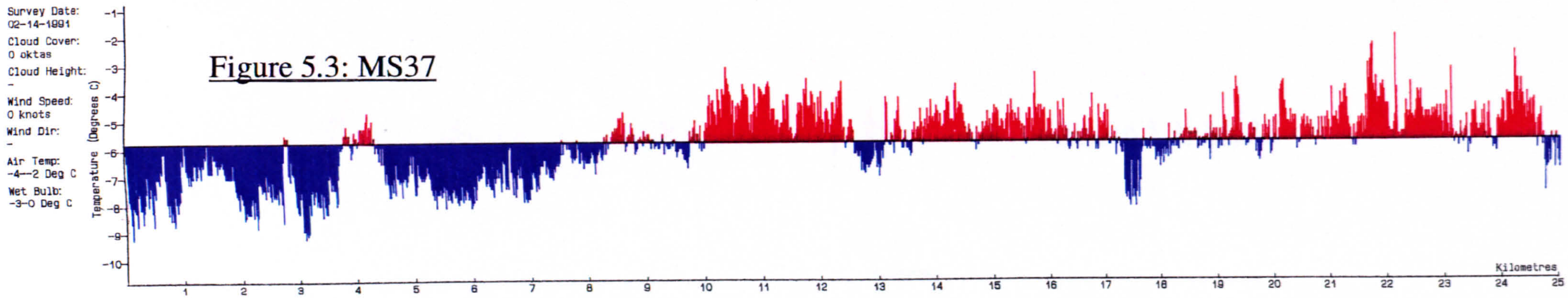


Figure 5.3: MS37

Extreme Fingerprints of Route 1 (continued)

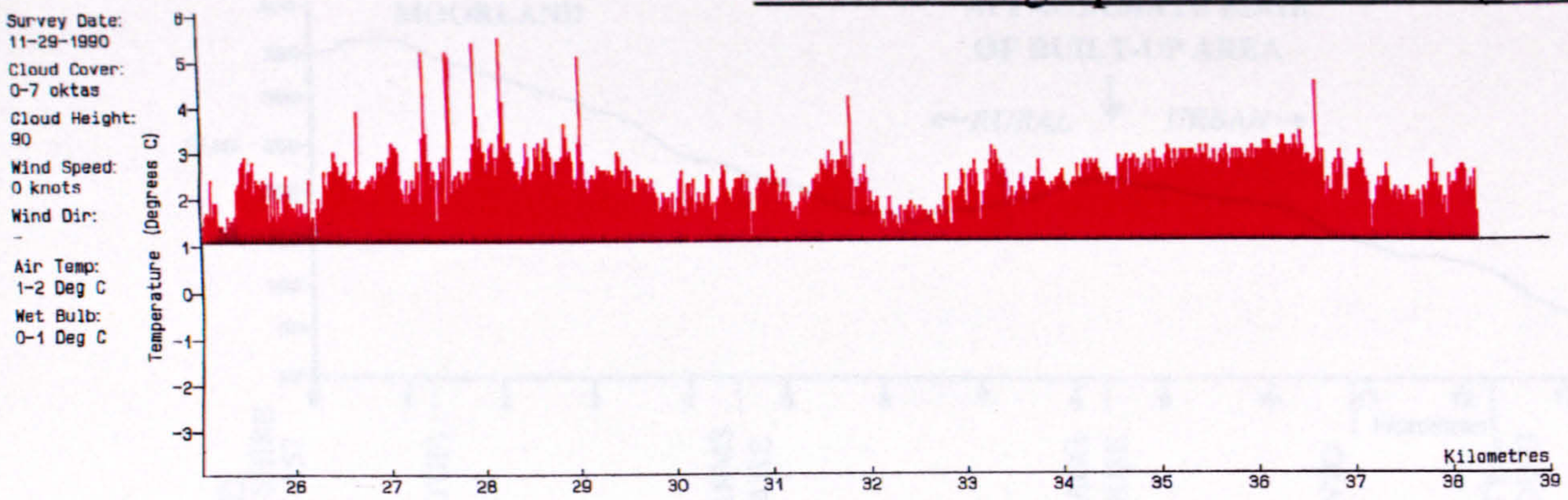


Figure 5.1: MS9

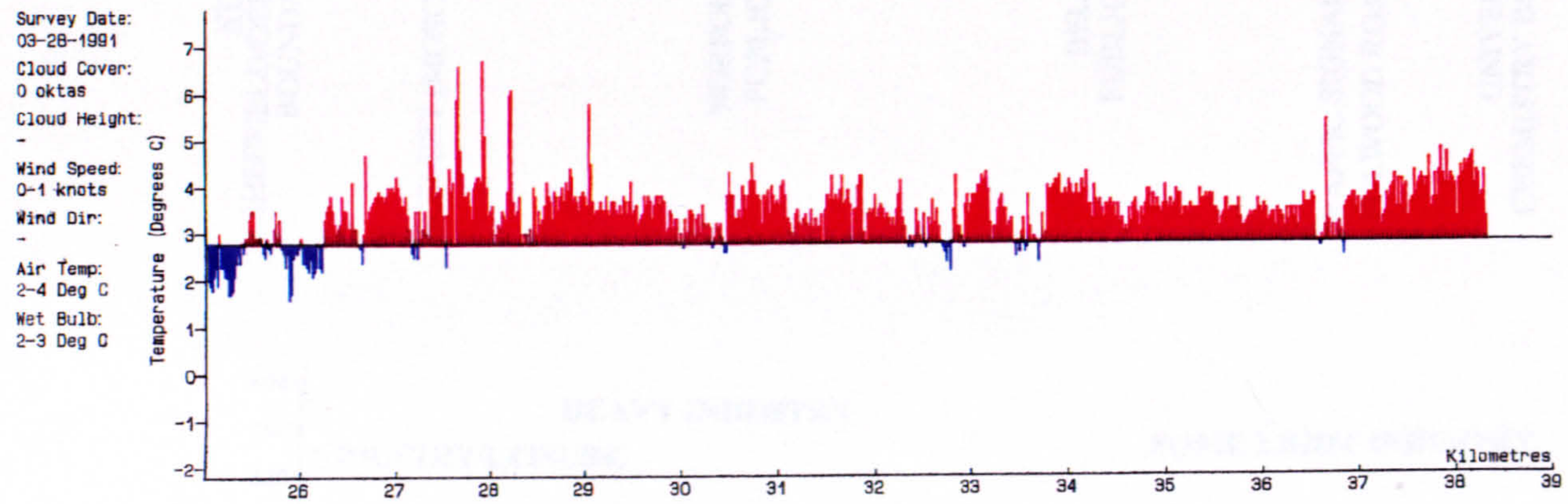


Figure 5.2: MS62

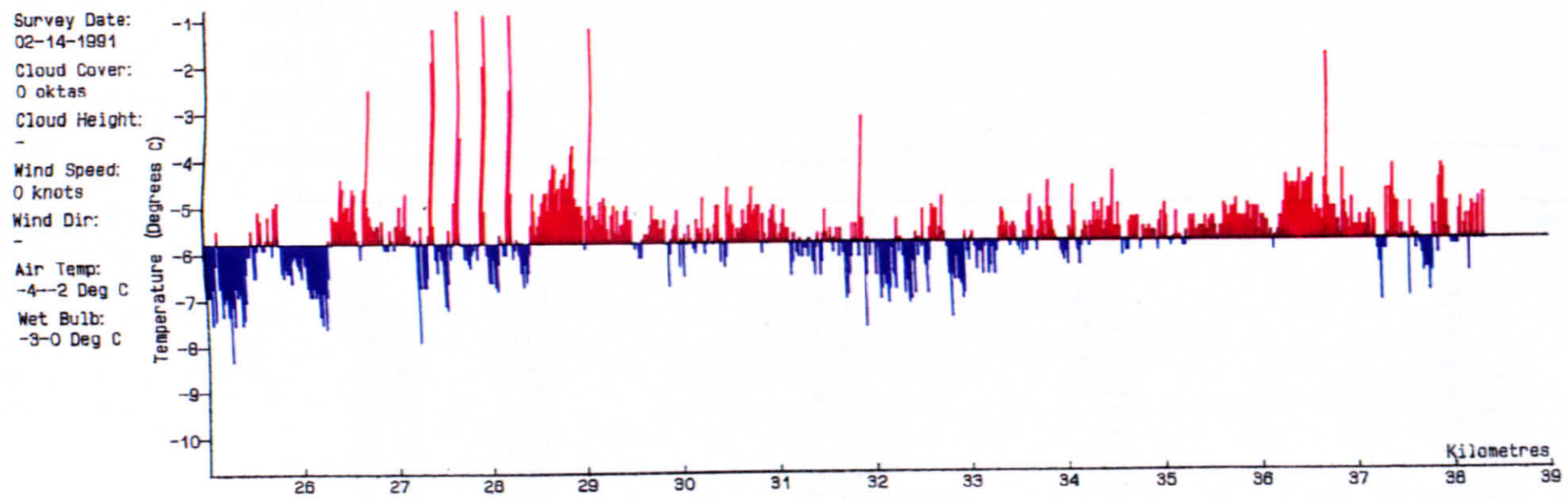


Figure 5.3: MS37

Figure 5.4: Altitude Profile of Route 1 with Land-Use and Location Details

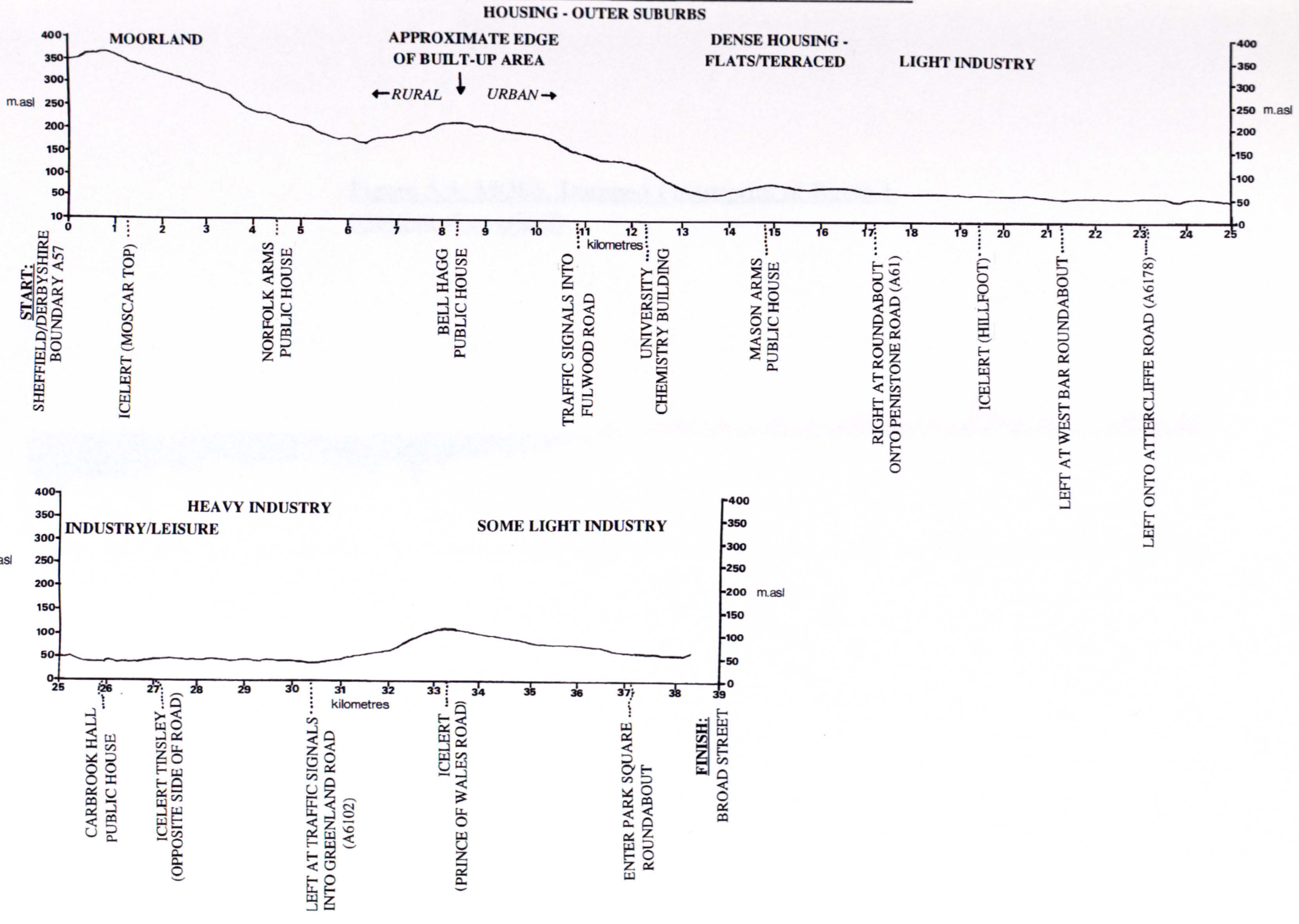


Figure 5.5: MOS5, Damped Fingerprint of Route 1
(continued overleaf)

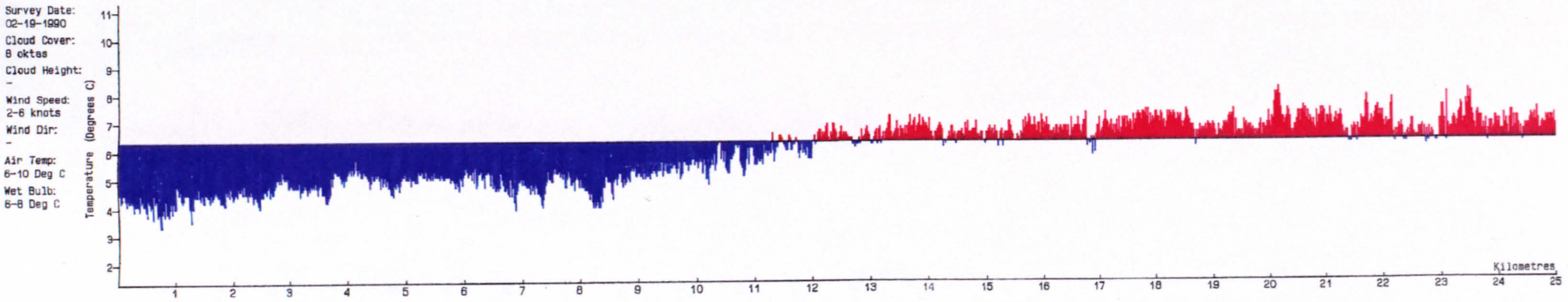
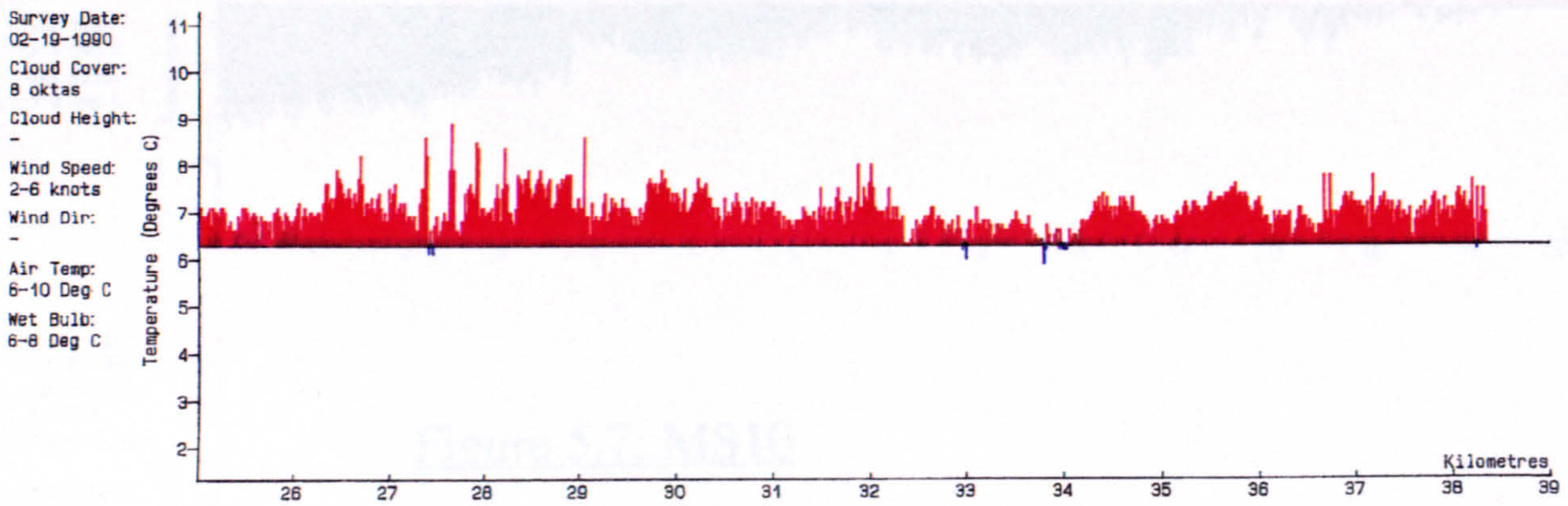


Figure 5.5: MOS5, Damped Fingerprint of Route 1 (continued)



Intermediate Fingerprints of Route 1 (continued overleaf)

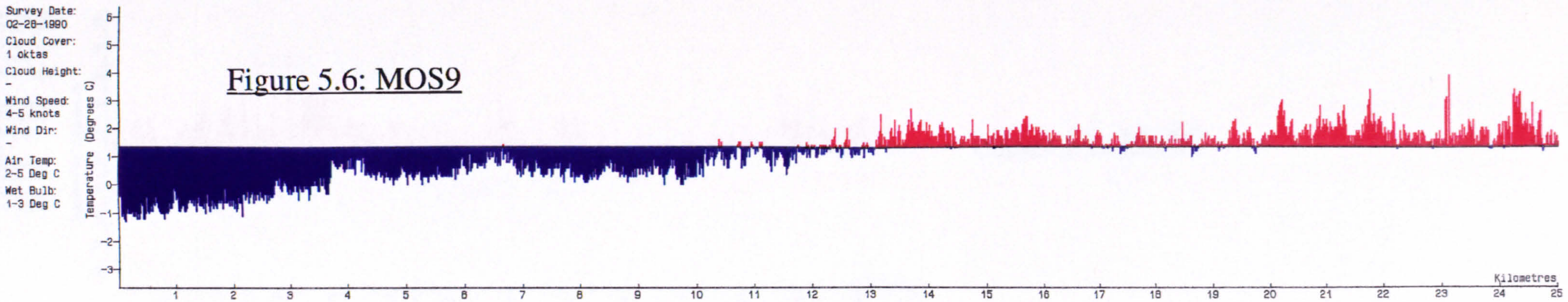


Figure 5.6: MOS9

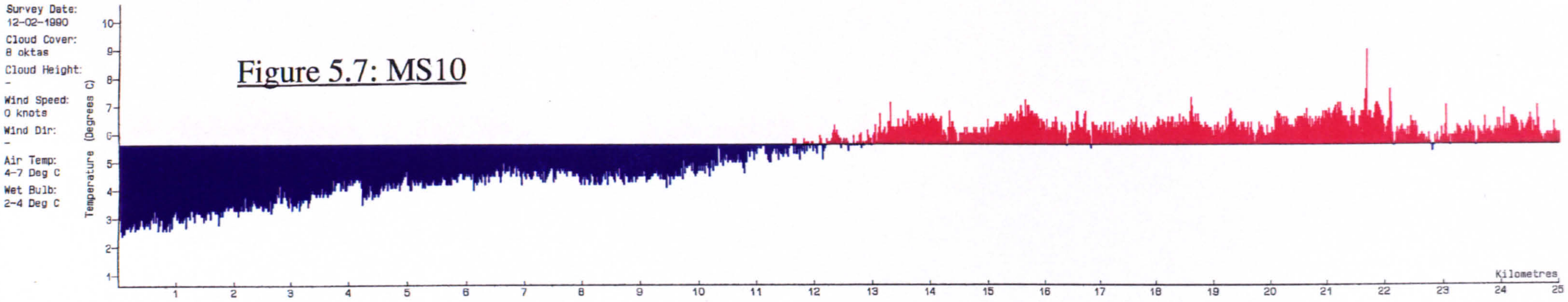


Figure 5.7: MS10

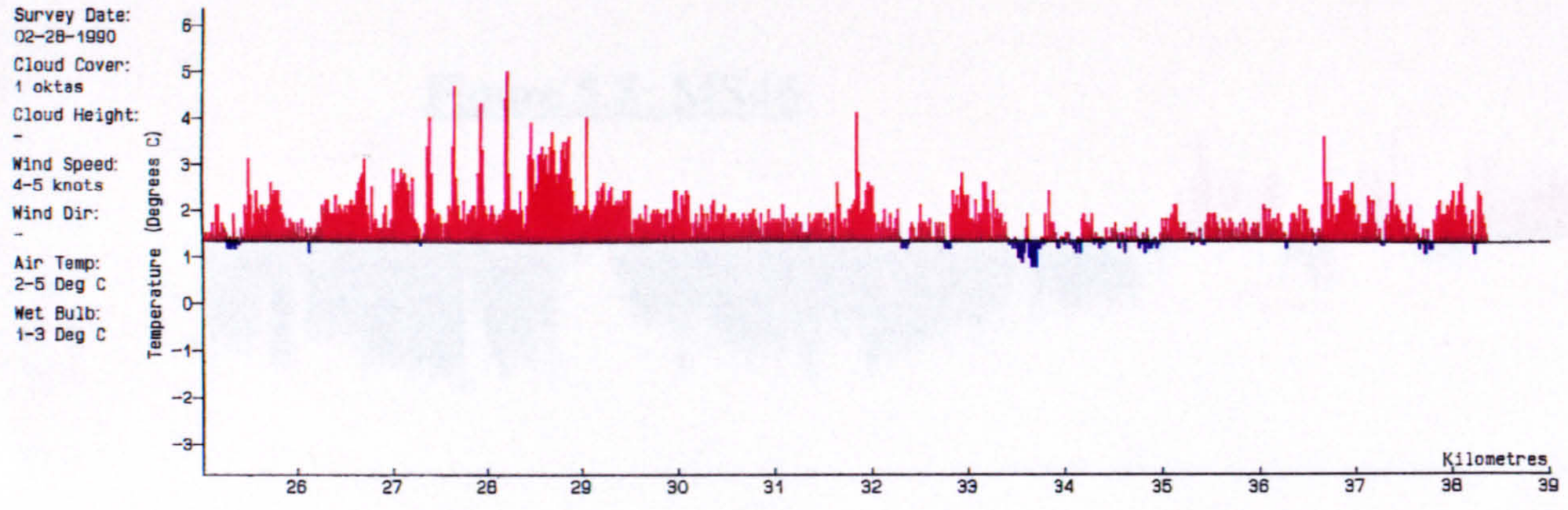


Figure 5.6: MOS9

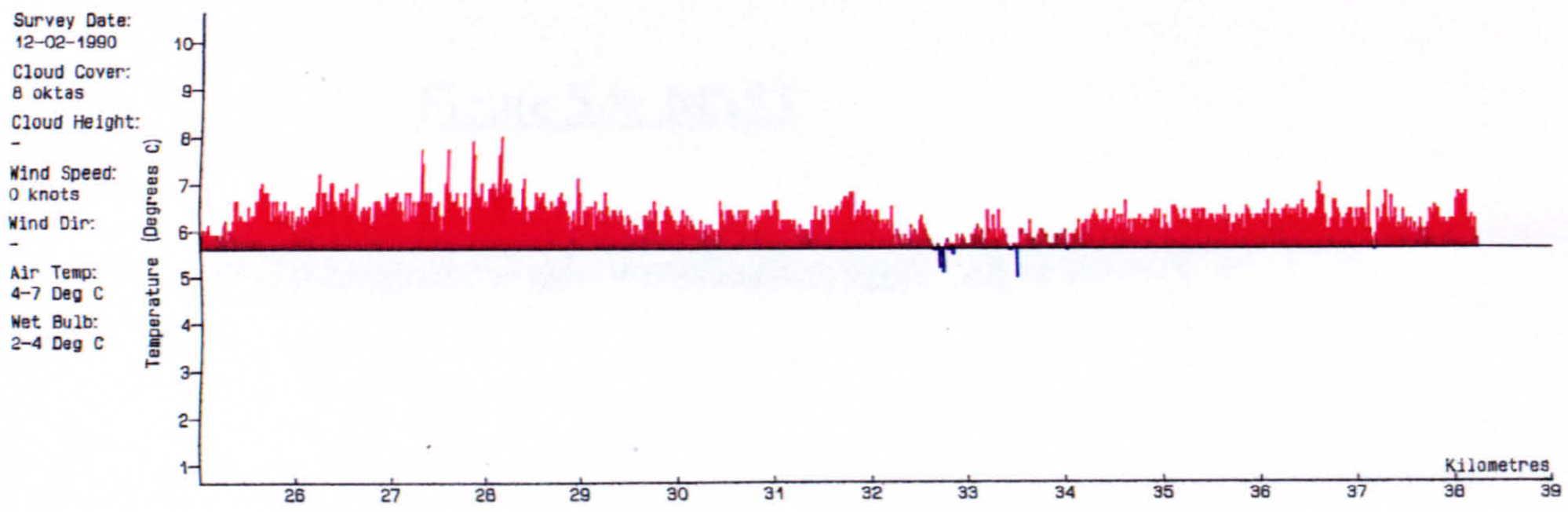


Figure 5.7: MS10

Fingerprints Showing the Effect of Fog (continued overleaf)

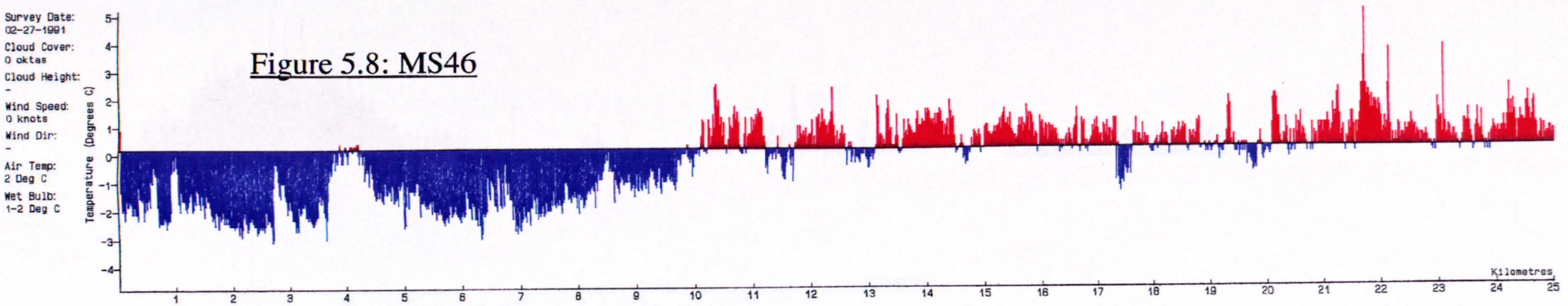


Figure 5.8: MS46

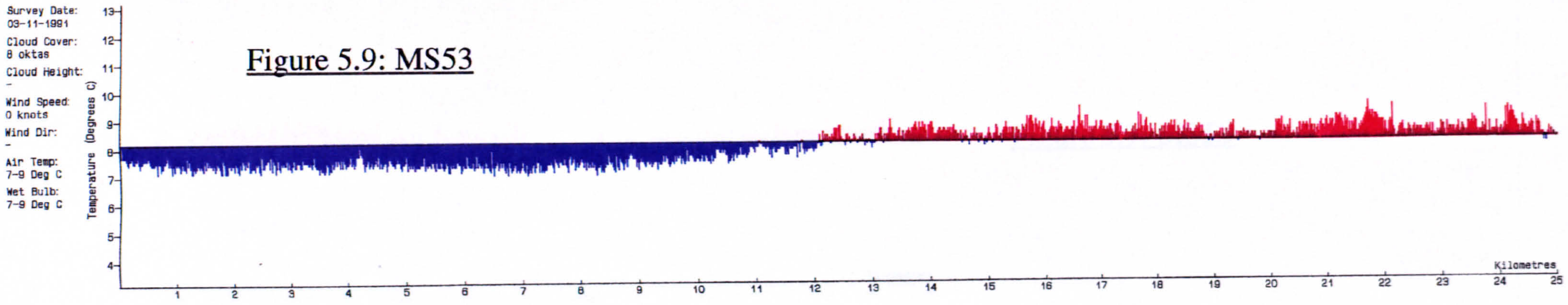


Figure 5.9: MS53

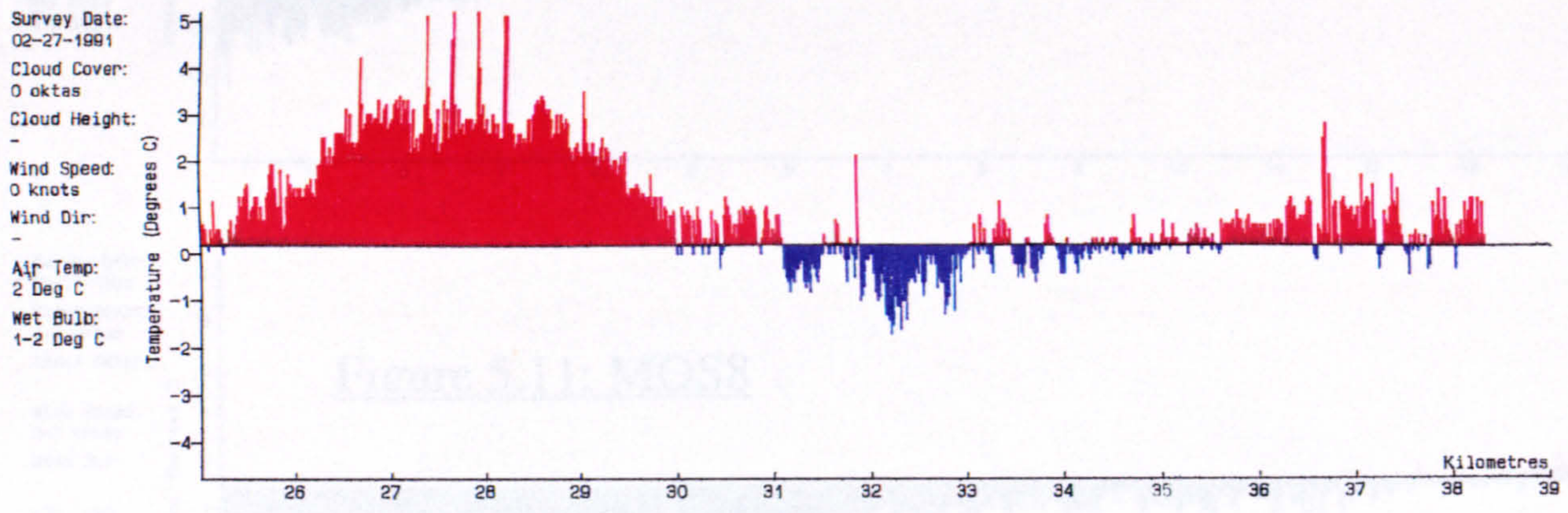


Figure 5.8: MS46

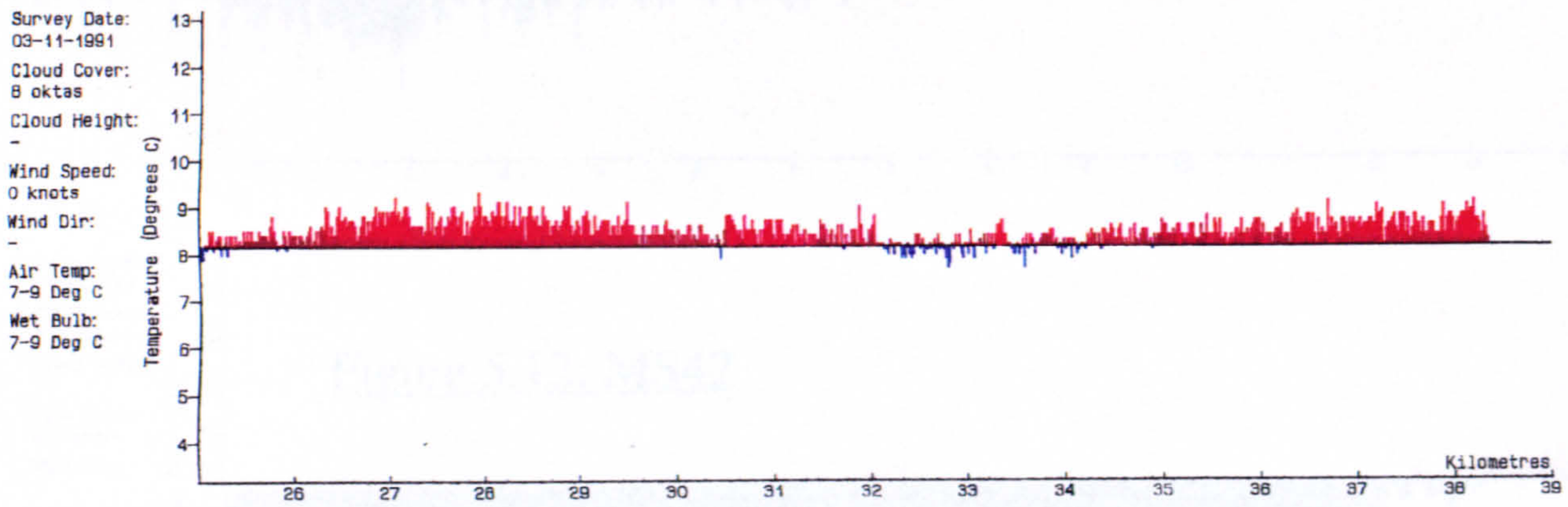


Figure 5.9: MS53

Fingerprints Showing the Effect of Snow/Slush/Water (continued overleaf)

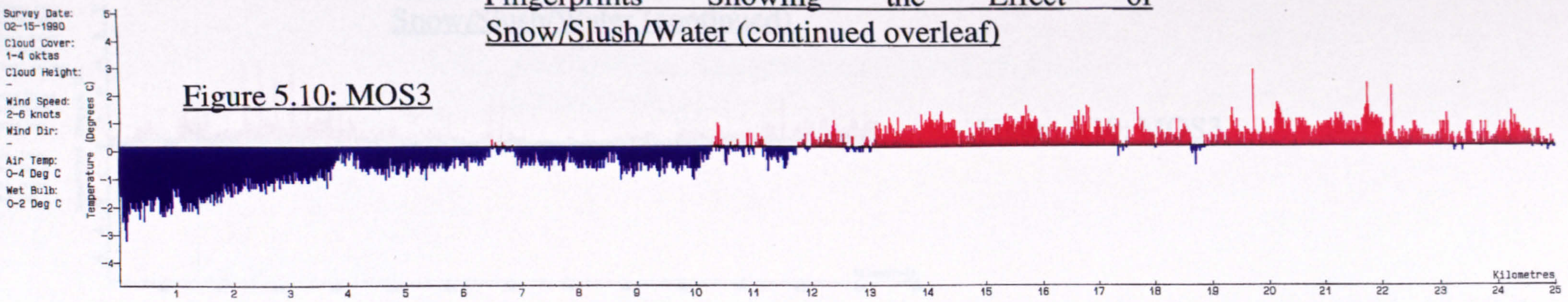


Figure 5.10: MOS3

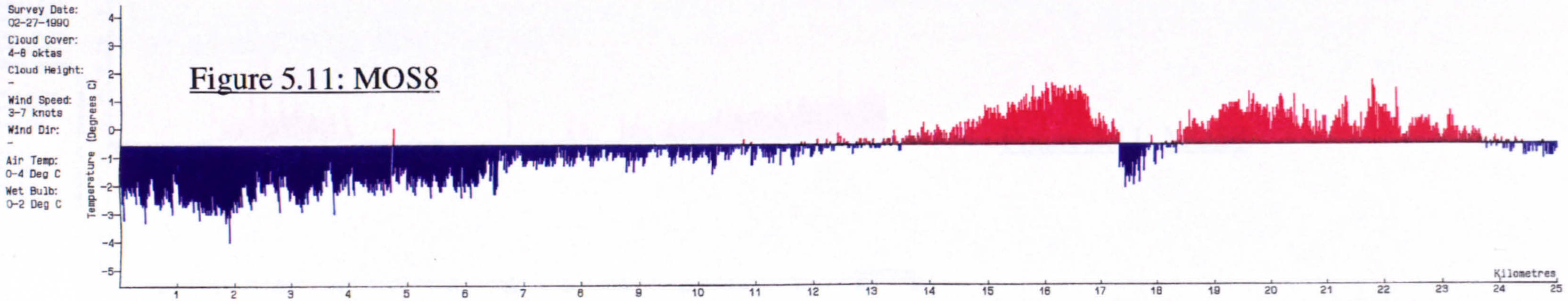


Figure 5.11: MOS8

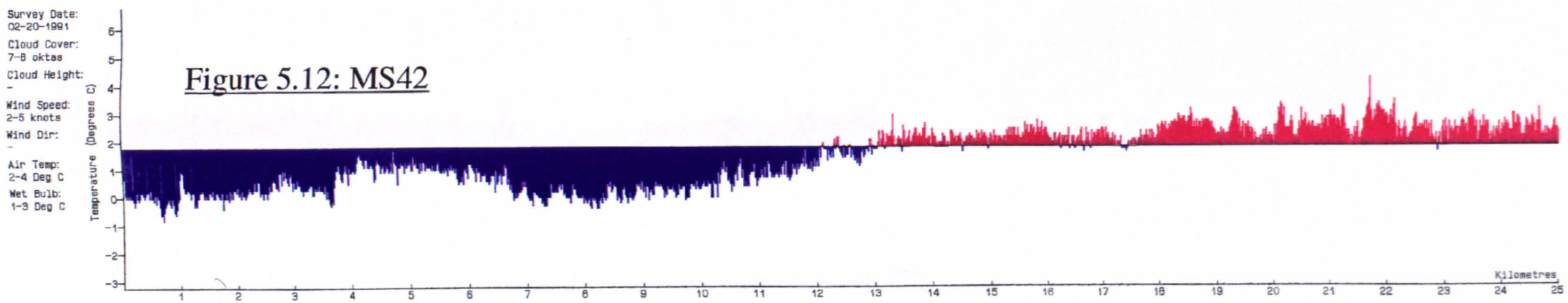


Figure 5.12: MS42

Fingerprints Showing the Effect of Snow/Slush/Water (continued)

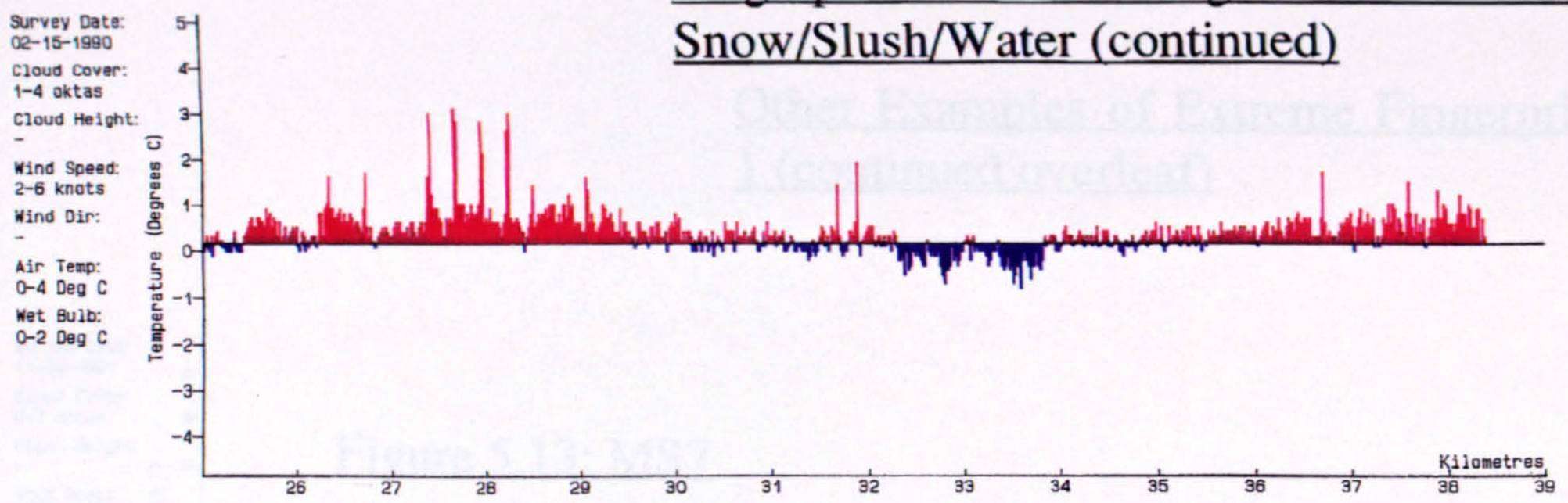


Figure 5.10: MOS3

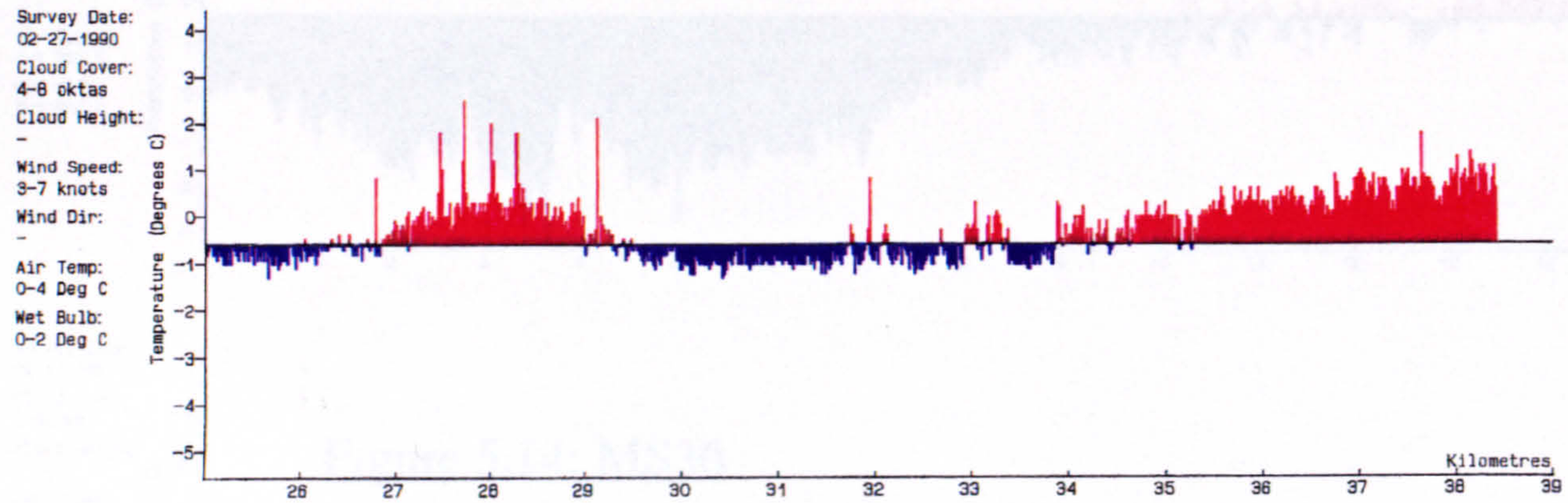


Figure 5.11: MOS8

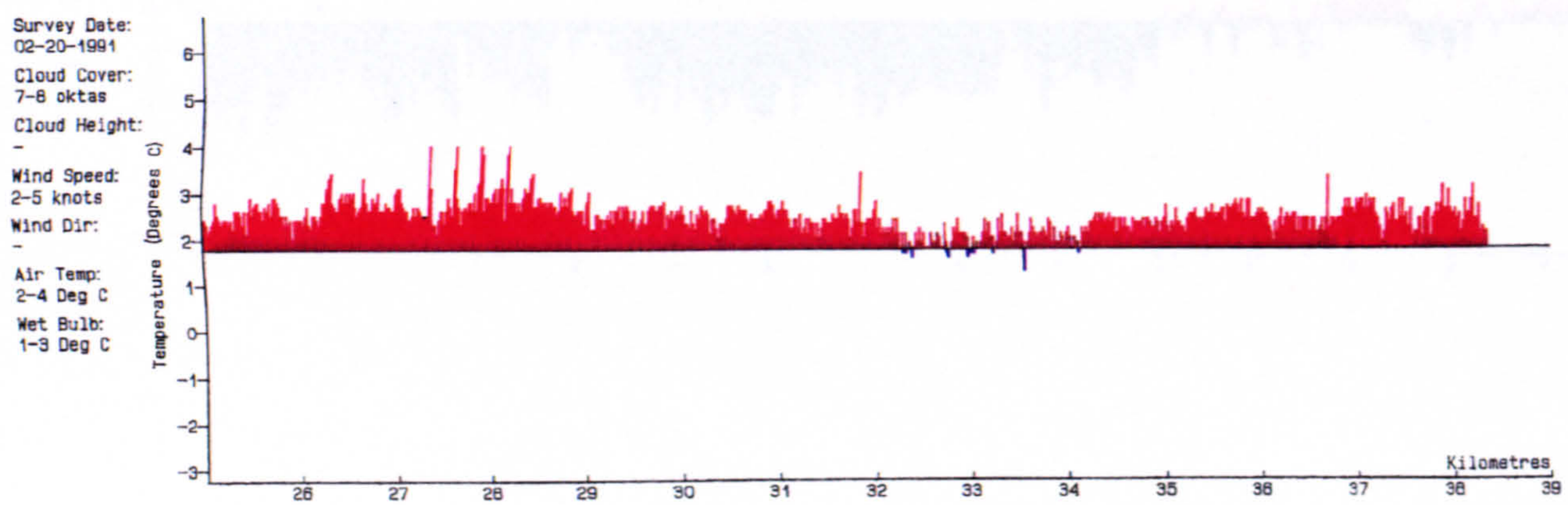


Figure 5.12: MS42

Other Examples of Extreme Fingerprints of Route 1 (continued overleaf)

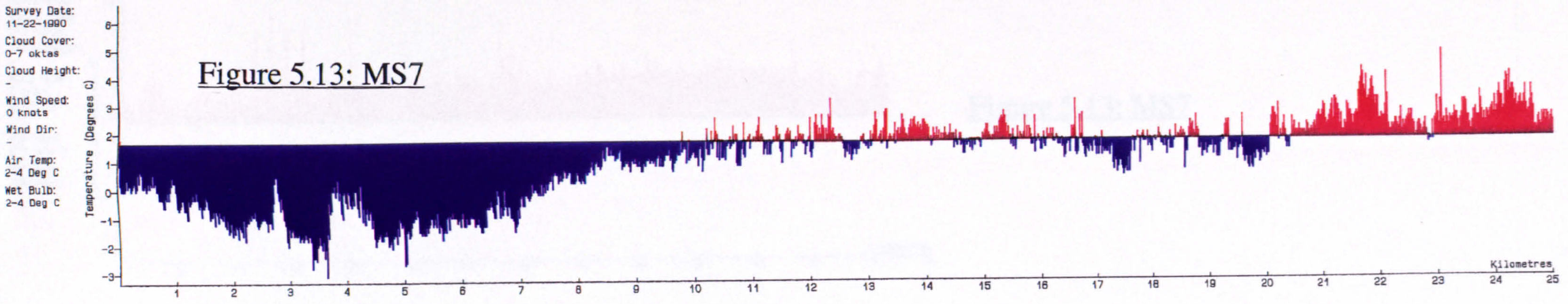


Figure 5.13: MS7

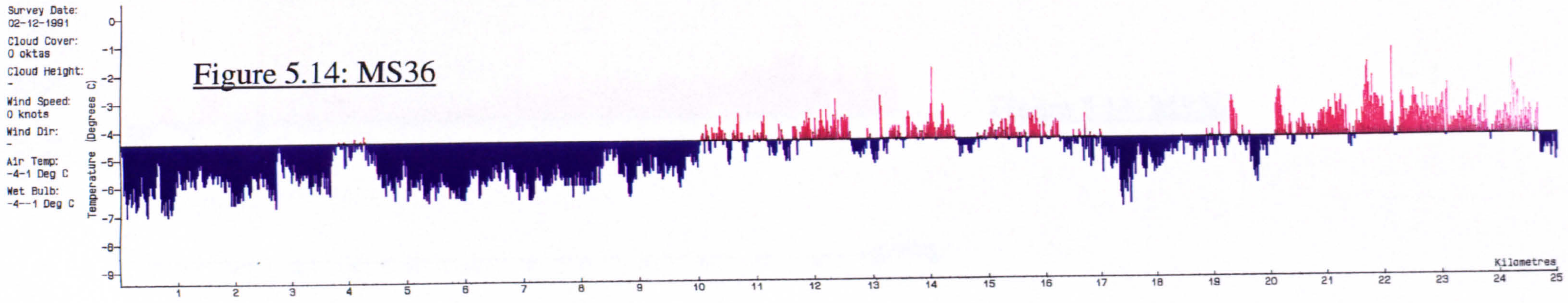


Figure 5.14: MS36

Other Examples of Extreme Fingerprints of Route 1 (continued)

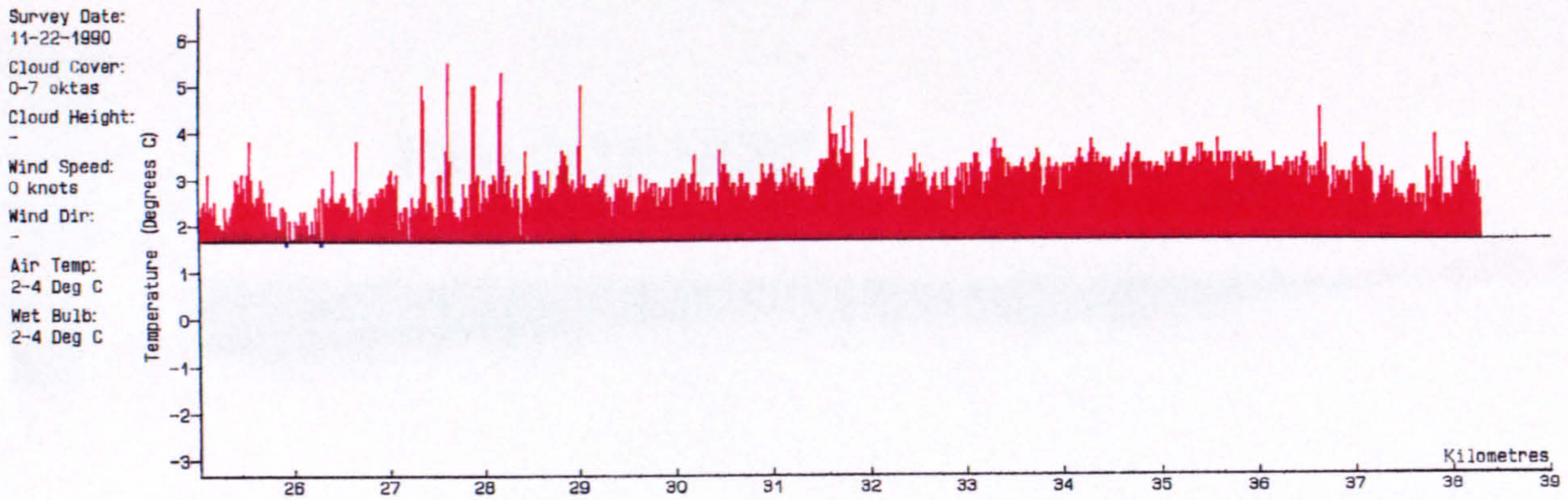


Figure 5.13: MS7

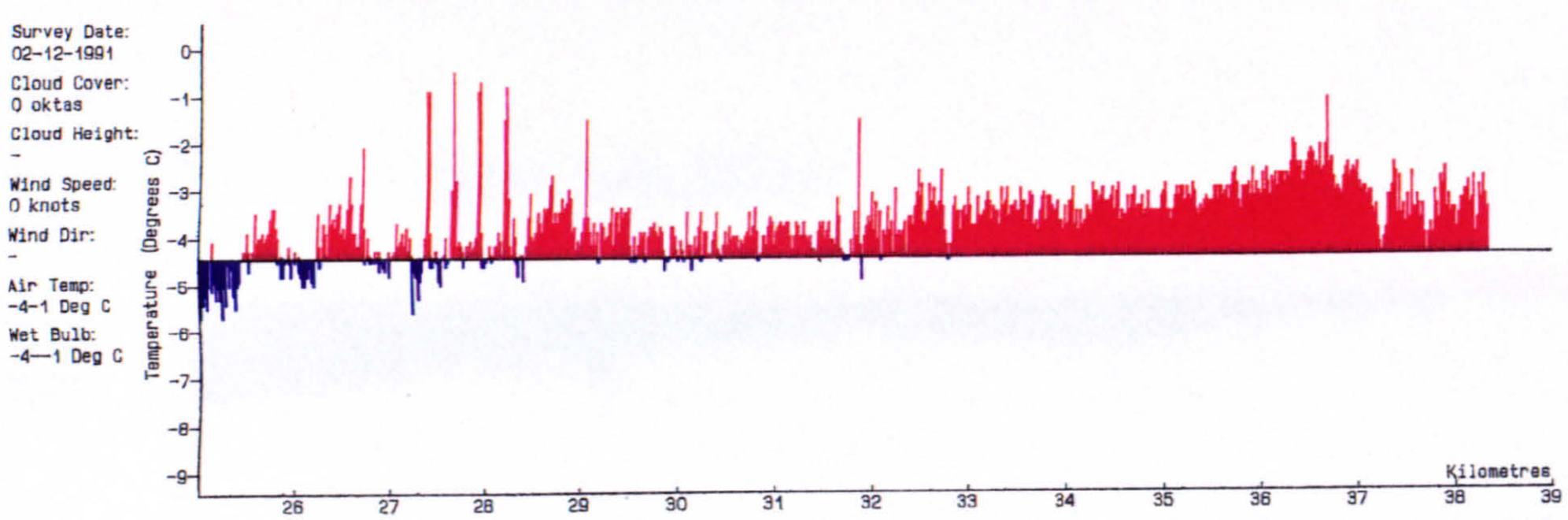


Figure 5.14: MS36

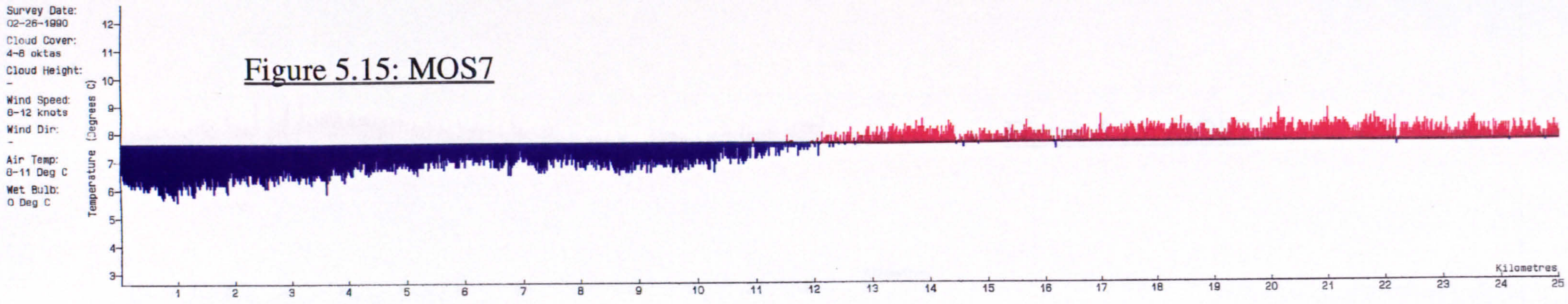


Figure 5.15: MOS7

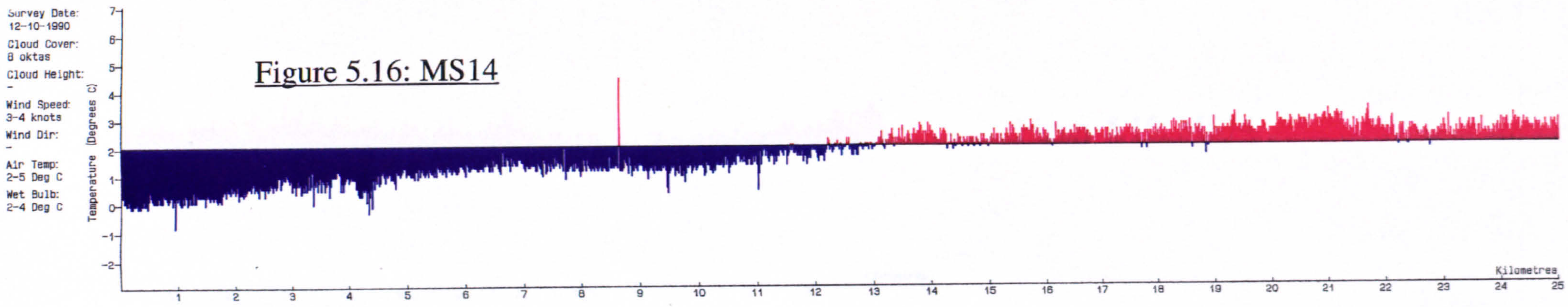


Figure 5.16: MS14

Other Examples of Damped Fingerprints of Route 1 (continued)

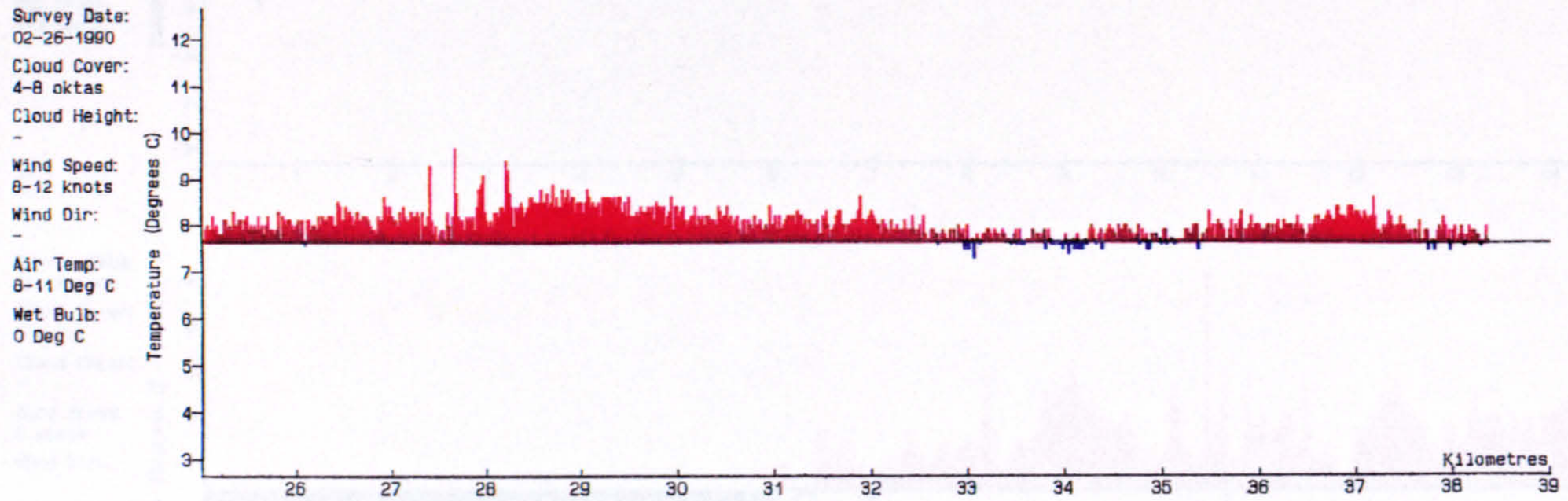


Figure 5.15: MOS7

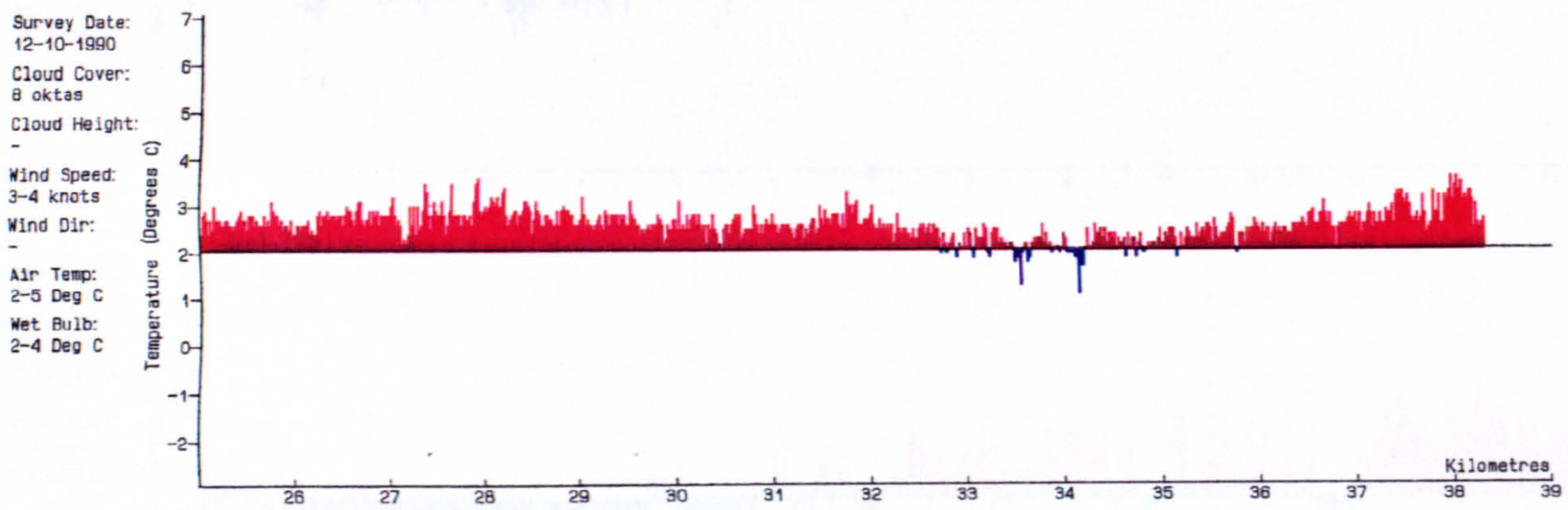


Figure 5.16: MS14

Extreme Fingerprints of Route 2

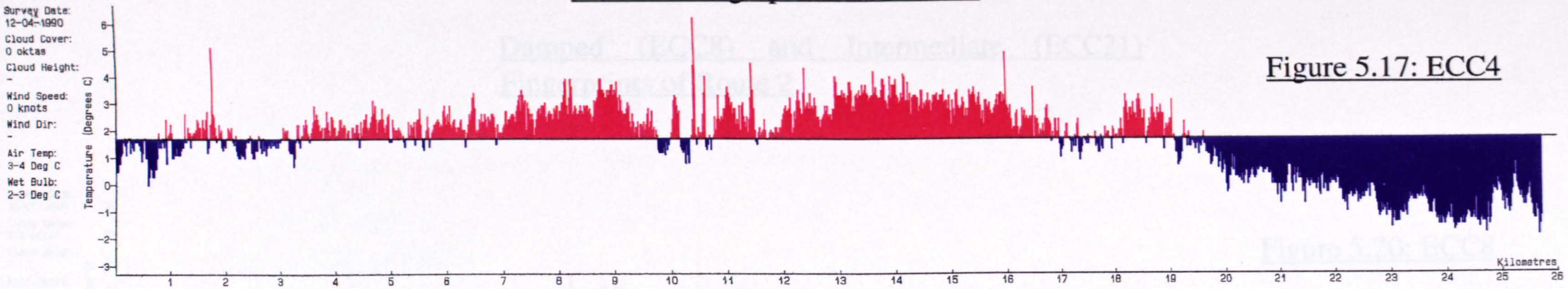


Figure 5.17: ECC4

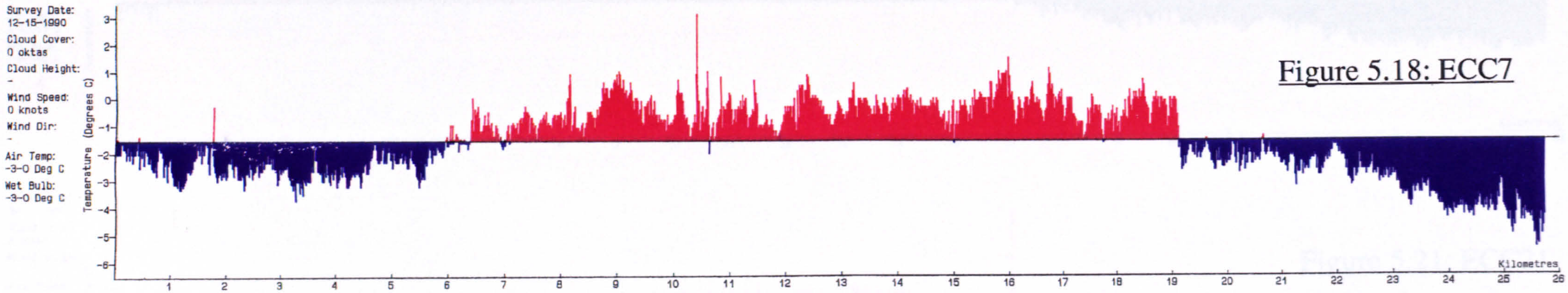


Figure 5.18: ECC7

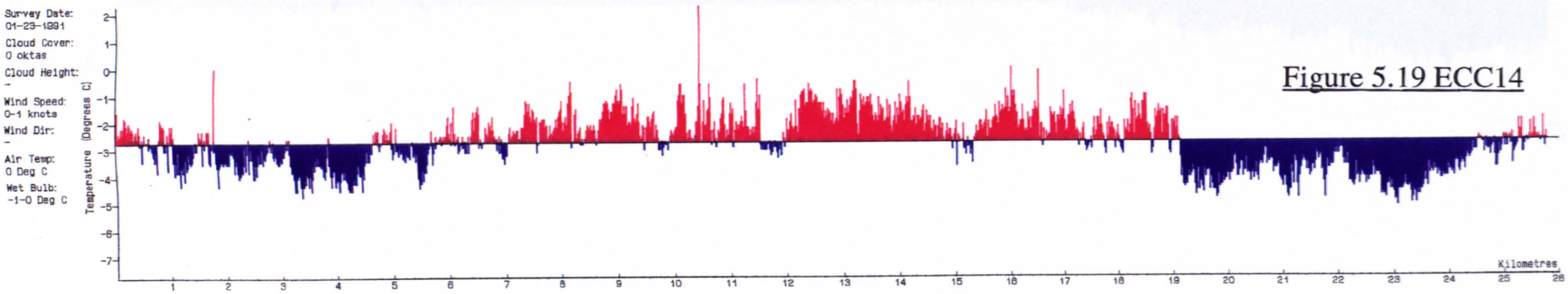


Figure 5.19 ECC14

Damped (ECC8) and Intermediate (ECC21) Fingerprints of Route 2

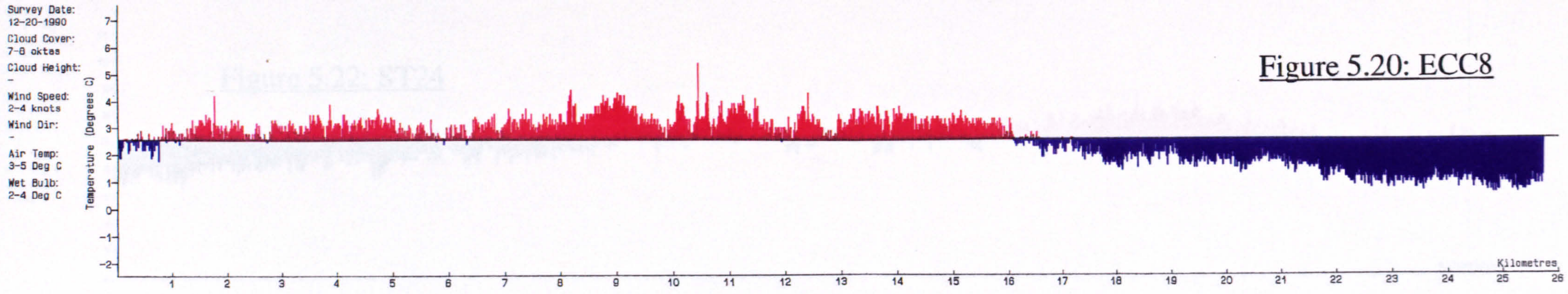


Figure 5.20: ECC8

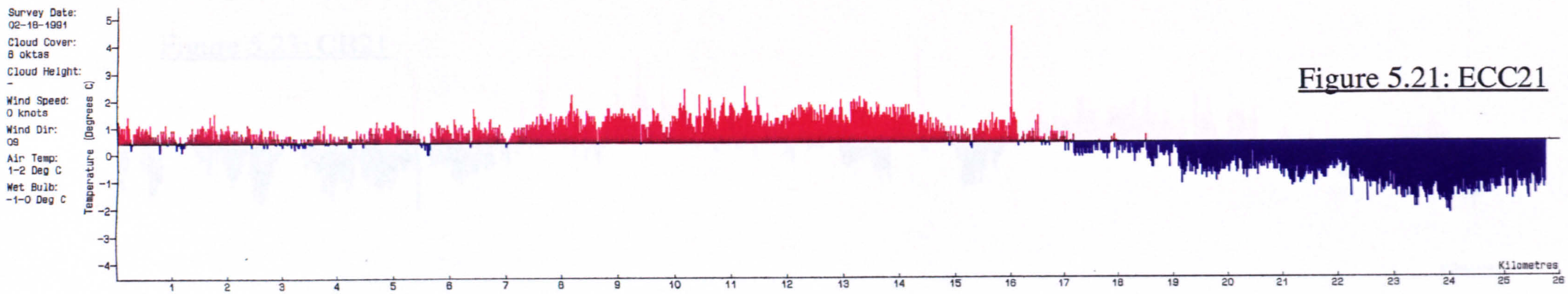


Figure 5.21: ECC21

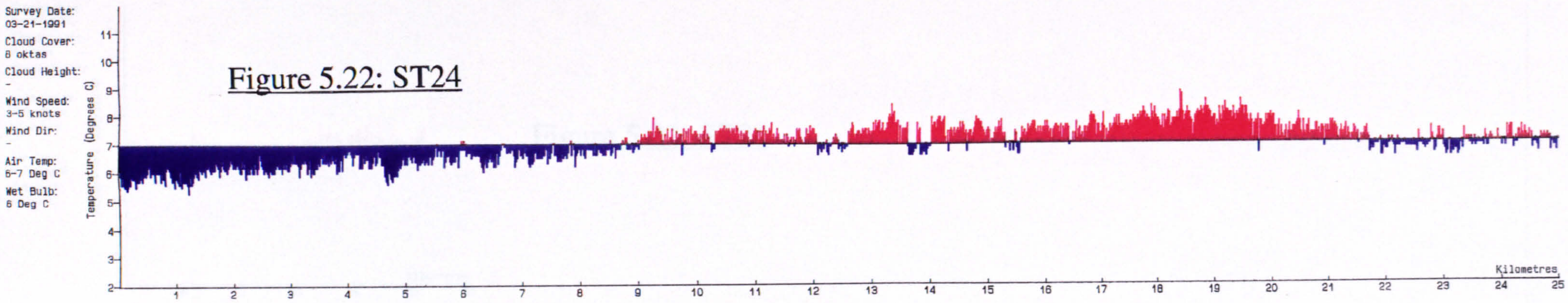


Figure 5.22: ST24

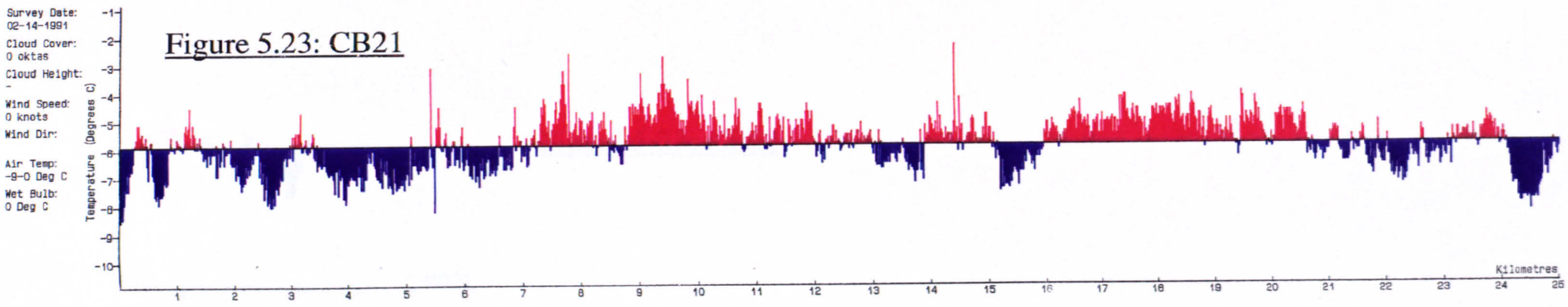


Figure 5.23: CB21

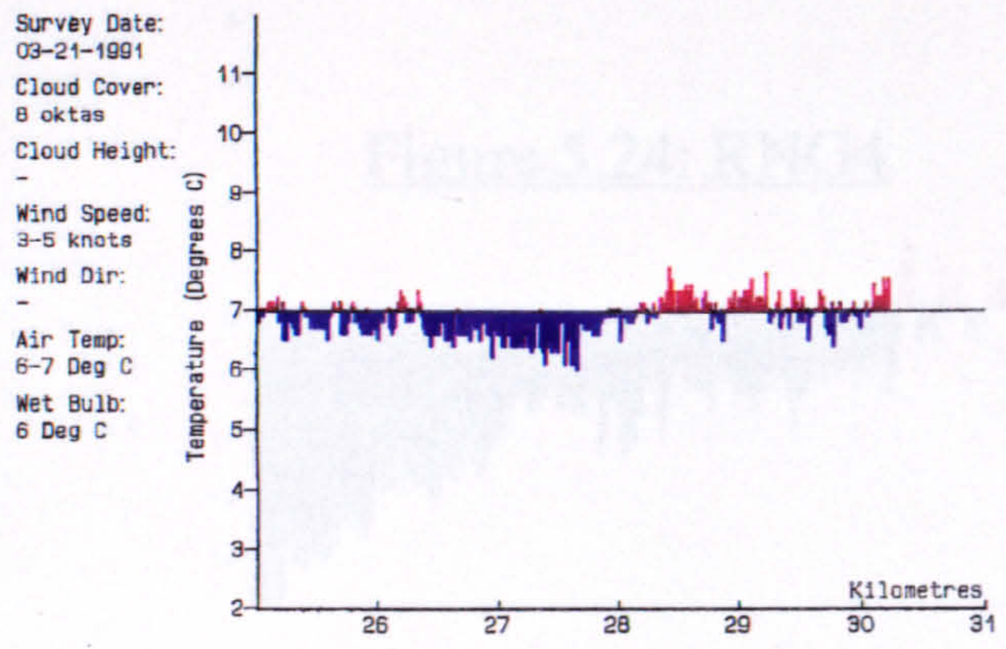


Figure 5.22: ST24

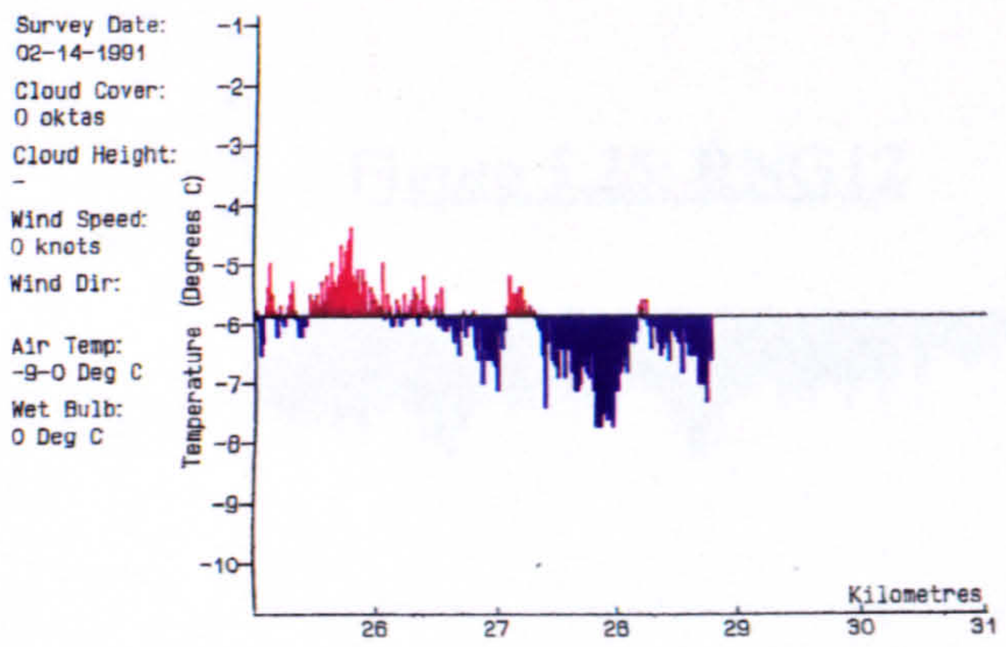


Figure 5.23: CB21

Extreme (RNG4) and Damped (RNG12) Fingerprints of Route 6 (continued overleaf)

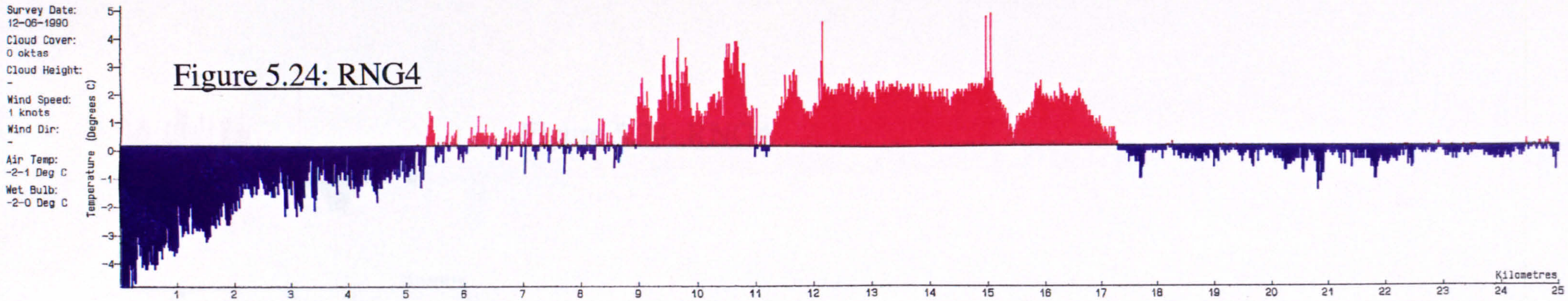


Figure 5.24: RNG4

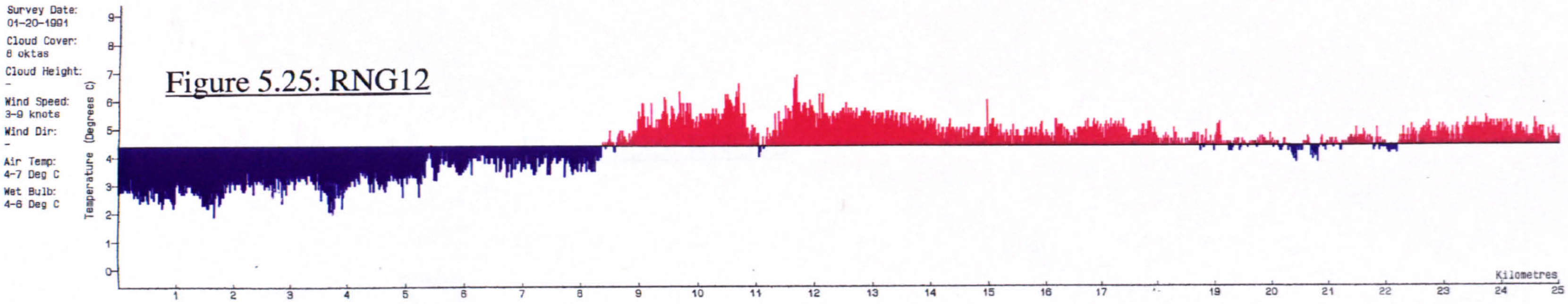


Figure 5.25: RNG12

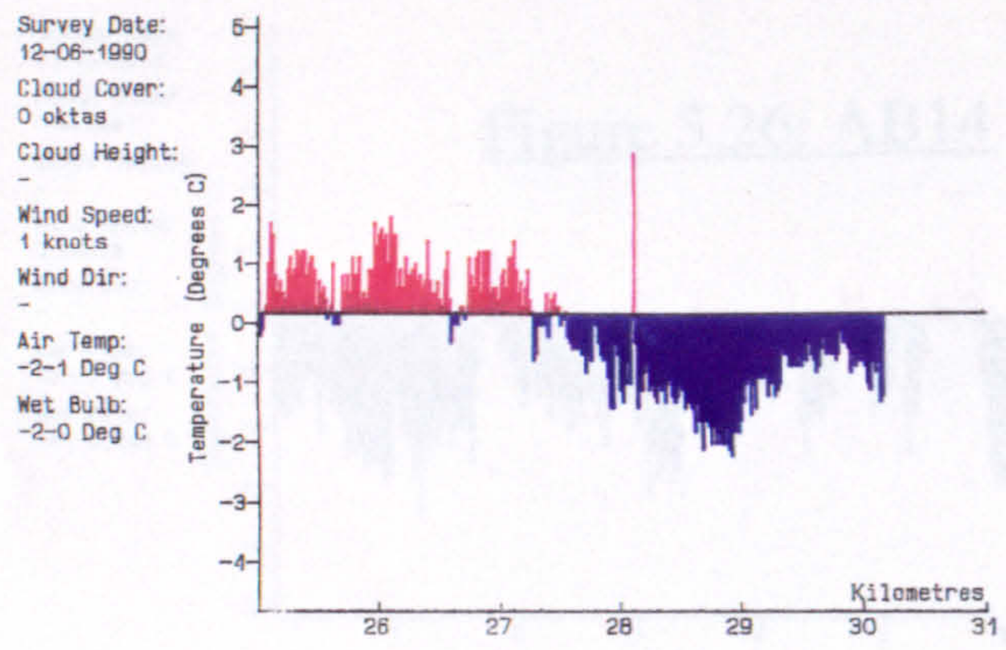


Figure 5.24: RNG4

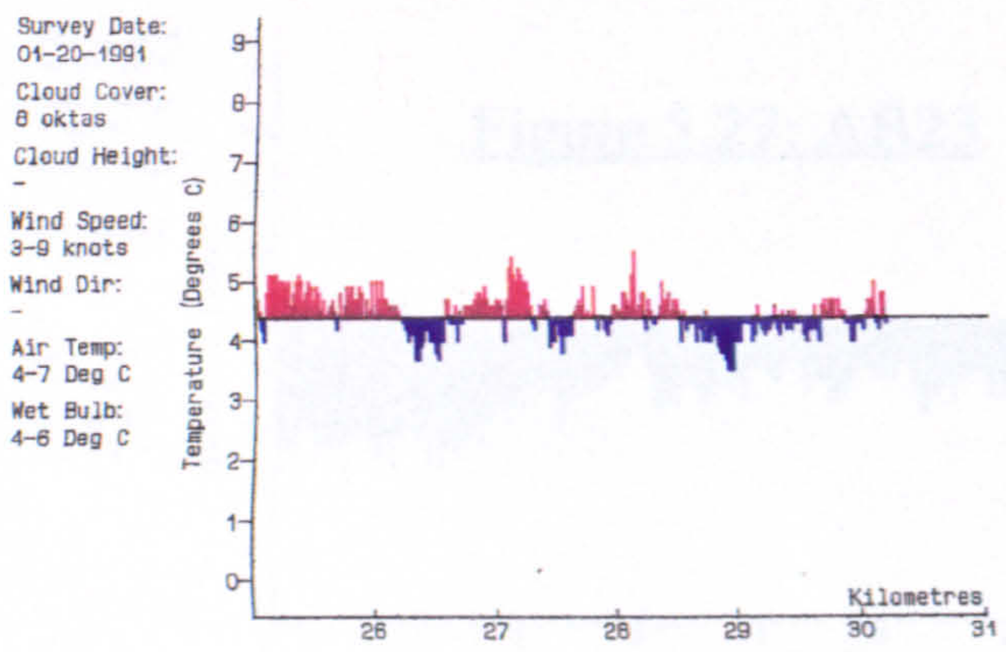


Figure 5.25: RNG12

Extreme (AB14) and Damped (AB23) Fingerprints of Route 7

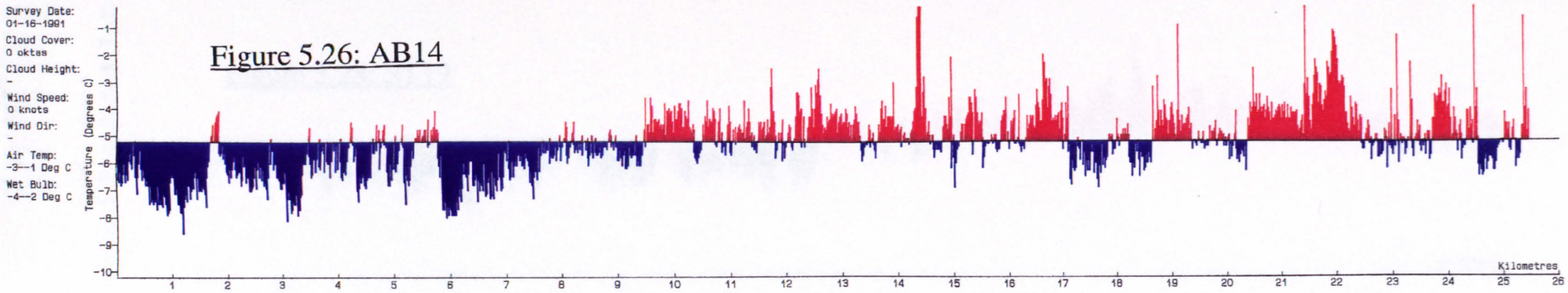


Figure 5.26: AB14

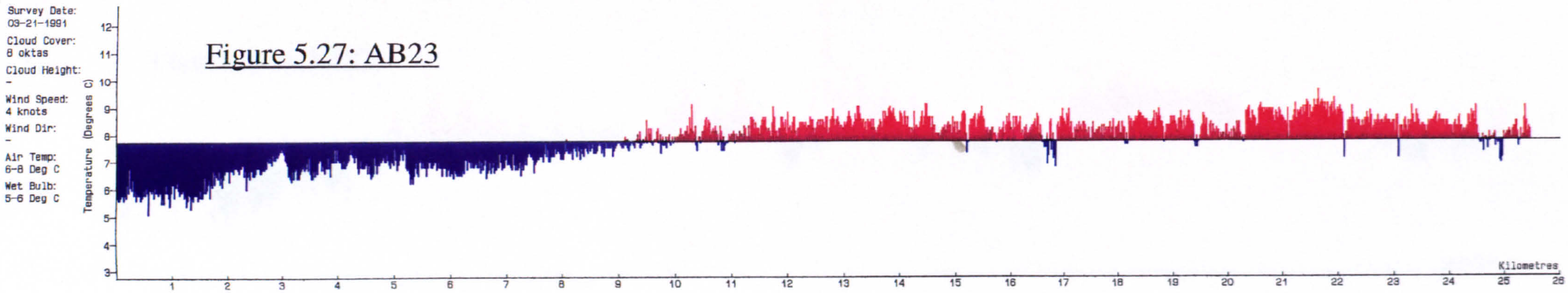


Figure 5.27: AB23

Extreme Fingerprints of Route 4 (ST19) and Route 3 (RIV5) (continued overleaf)

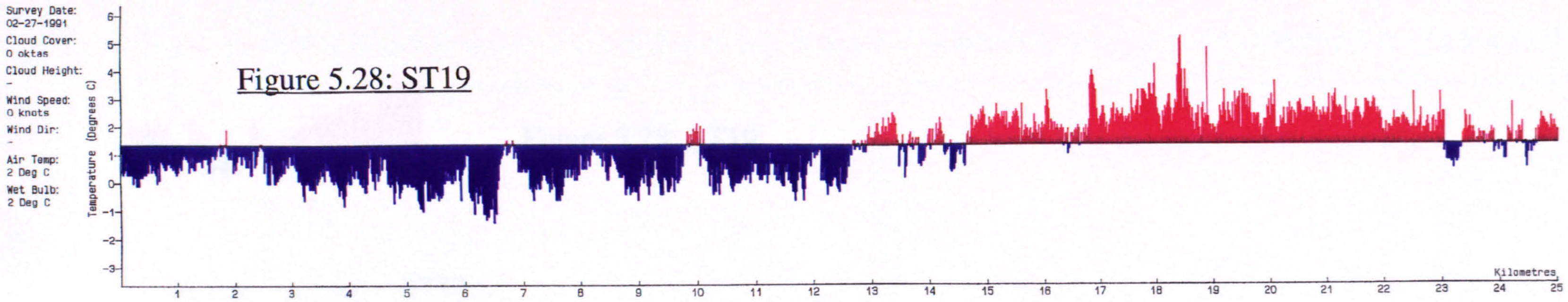


Figure 5.28: ST19

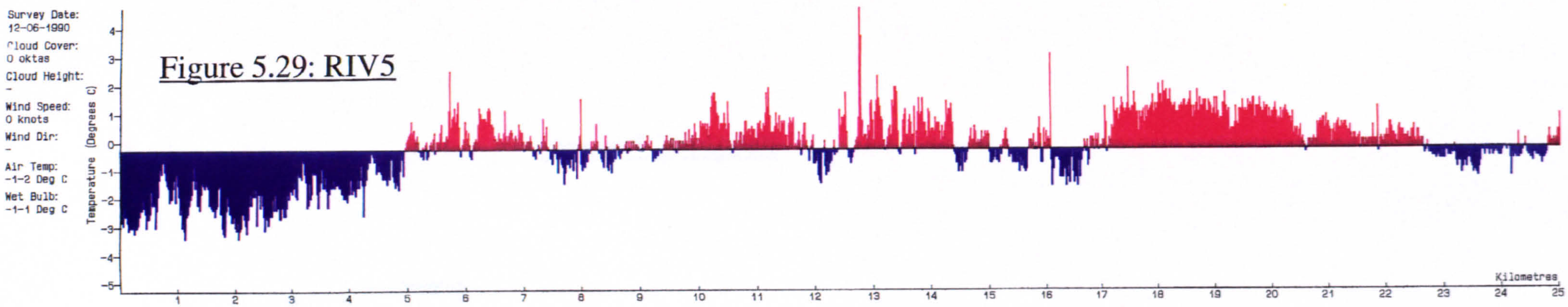


Figure 5.29: RIV5

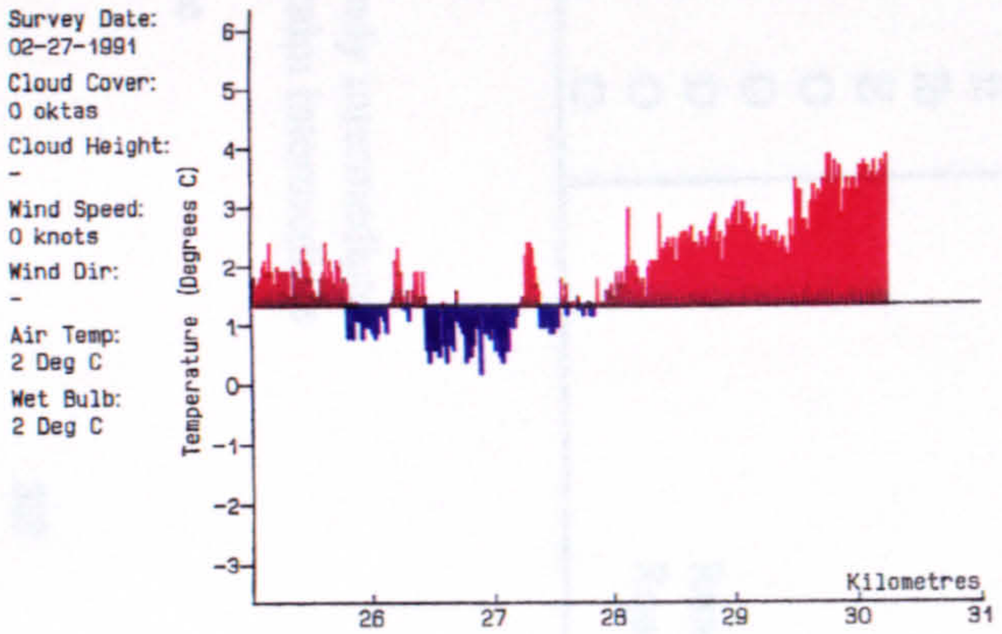


Figure 5.28: ST19

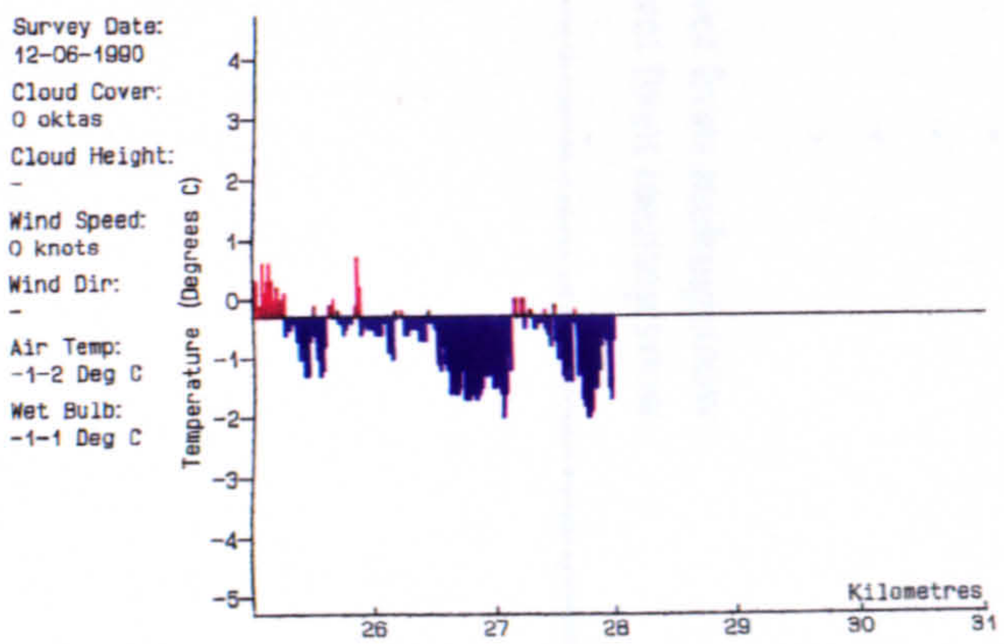


Figure 5.29: RIV5

Table 5.1: Details of Runs Along Route 1 Commencing at 0430hrs (continued overleaf)

Run	Date	Class[1]	Notes
MOS2	14.2.90	0	Heavy rain 0-5km, wet roads all run
MOS3	15.2.90	0	Patchy/thin snow (fresh) on roads 0-4km
MOS4	17.2.90	D?	Foggy tops
MOS5	19.2.90	D	-
MOS6	22.2.90	O	-
MOS7	26.2.90	D	Heavy rain showers roads, especially tops very wet
MOS8	27.2.90	D?	Snow/slush on roads, very wet - snow showers during run
MOS9	28.2.90	Ia?	-
MOS10	1.3.90	O	Snow showers, snow on roads in places 0-13km
MOS11	2.3.90	E	-
MOS12	5.3.90	O	-
MOS13	6.3.90	O	-
MOS14	7.3.90	D?	-
MOS15	8.3.90	O	-
MOS16	9.3.90	O	Wet roads
MOS17	10.3.90	D	-
MOS18	13.3.90	O	-
MOS19	14.3.90	O	-
MOS20	16.3.90	D?	-
MOS21	19.3.90	O	-
MOS22	22.3.90	E?	-
MOS23	25.3.90	O	-
MOS24	26.3.90	E	-
MOS25	31.3.90	Ib	-
MOS26	3.4.90	O	-
MOS27	4.4.90	O	-
MOS28	17.4.90	O	-
DV1B	16.2.90	E	Slight, old snow cover Moscar Top-3.5km and Crosspool
DV2B	3.3.90	O	-
DV3B	12.3.90	O	-
DV4B	18.3.90	O	-
DV5B	20.3.90	E?	-
DV6B	29.3.90	O	-
DV7B	5.4.90	E	-
MS1	4.11.90	O	-
MS2	7.11.90	Ib?	Tops foggy
MS3	8.11.90	O	-
MS4	19.11.90	O	-
MS5	20.11.90	O	-
MS6	21.11.90	O	-
MS7	22.11.90	E	-
MS8	27.11.90	O	Wet roads
MS9	29.11.90	E	-
MS10	2.12.90	Ib	-
MS11	4.12.90	E	-
MS12	5.12.90	O	-
MS13	6.12.90	O	-
MS14	10.12.90	D	Roads wet from melting snow
MS15	12.12.90	O	Roads wet from melting snow
MS16	13.12.90	O	-

NOTES: 1) E = extreme
D = damped
Ia = clear/windy intermediate
Ib = cloudy/calm intermediate
0 = others
? = borderline

Table 5.1: Details of Runs Along Route 1 Commencing at 0430hrs (continued)

Run	Date	Class[1]	Notes
MS17	15.12.90	E	-
MS18	20.12.90	D?	Wet roads
MS19	21.12.90	O	-
MS20	29.12.90	O	-
MS21	31.12.90	O	-
MS22	3.1.91	O	-
MS23	4.1.91	O	Very light snow cover 9.8-10.2km
MS24	8.1.91	O	-
MS25	10.1.91	O	-
MS26	13.1.91	E	-
MS27	16.1.91	E	-
MS28	20.1.91	D	-
MS29	23.1.91	E	-
MS30	26.1.91	Ib?	-
MS31	29.1.91	Ib?	-
MS32	30.1.91	Ib	-
MS33	31.1.91	Ib?	-
MS34	5.2.91	O	-
MS35	6.2.91	O	-
MS36	12.2.91	E	-
MS37	14.2.91	E	-
MS38	16.2.91	E	-
MS39	17.2.91	O	-
MS40	18.2.91	Ib?	-
MS41	19.2.91	E	-
MS42	20.2.91	D?	-
MS43	21.2.91	O	-
MS44	22.2.91	O	Snow/slush on roads 0-3.5km, then wet
MS45	26.2.91	O	-
MS46	27.2.91	E	Very foggy 22.9-30.90km
MS47	1.3.91	E?	-
MS48	4.3.91	O	-
MS49	5.3.91	O	-
MS50	6.3.91	Ib?	Wet roads
MS51	8.3.91	O	-
MS52	9.3.91	O	-
MS53	11.3.91	Ib	Mist/fog in places especially tops
MS54	13.3.91	0	Misty/foggy tops
MS55	15.3.91	0	-
MS56	16.3.91	0	-
MS57	20.3.91	0	-
MS58	22.3.91	0	-
MS59	24.3.91	0	-
MS60	25.3.91	0	-
MS61	26.3.91	0	-
MS62	28.3.91	E	-
MS63	3.4.91	O	-
MS64	4.4.91	O	-
MS65	9.4.91	O	-
MS66	17.4.91	O	-

NOTES: 1) E = extreme
D = damped
Ia = clear/windy intermediate
Ib = cloudy/calm intermediate
0 = others
? = borderline

Table 5.2: Lapse Rates (RST) For Extreme Runs

Run	Rural Lapse Rate[1] (°C/100m)	Urban Lapse Rate[2] (°C/100m)	Overall Lapse Rate[3] (°C/100m)
MOS11	-0.74	-1.06	-0.97
MOS24	-0.68	-0.81	-1.09
DV1B	-0.16	-0.81	-0.63
DV7B	-0.74	+0.19	-0.78
MS7	+0.74	-0.75	-0.66
MS9	-0.11	-1.38	-1.22
MS11	-0.90	-1.38	-1.19
MS17	-0.16	-0.50	-0.53
MS26	+0.05	-0.38	-0.28
MS27	-0.21	-0.06	-0.22
MS29	-0.05	-0.81	-0.78
MS36	-0.21	-0.50	-0.53
MS37	-0.11	+0.63	-0.28
MS38	-0.05	-1.06	-0.72
MS41	+0.32	-0.31	-0.50
MS46	+0.47	-1.56	-0.91
MS62	0.00	-0.56	-0.50
Average	-0.15	-0.65	-0.69
SD	0.42	0.56	0.30

Table 5.3: Lapse Rates (RST) For Damped Runs

Run	Rural Lapse Rate[1] (°C/100m)	Urban Lapse Rate[2] (°C/100m)	Overall Lapse Rate[3] (°C/100m)
MOS5	-0.47	-1.65	-1.65
MOS7	-0.53	-0.82	-0.63
MOS17	-0.42	-0.77	-0.66
MS14	-0.58	-0.77	-0.78
MS28	0.00	-1.06	-0.44
Average	-0.40	-1.01	-0.83
SD	0.21	0.34	0.42

NOTES: 1) Moscar Top (0.5km, 360m.asl) to Rivelin Valley (6.3km, 170m.asl)
2) Crosspool (9km, 200m.asl) to Attercliffe (26km, 40m.asl)
3) Moscar Top (0.5km, 360m.asl) to Attercliffe (26km, 40m.asl)

Table 5.4: Overall and Rural Lapse Rates (RST) For 100 Runs Along Route 1

Run	Overall Lapse Rate (°C/100m)[1]	Rural Lapse Rate (°C/100m)[2]	Run	Overall Lapse Rate (°C/100m)[1]	Rural Lapse Rate (°C/100m)[2]
MOS2	-0.59	-0.68	MS17	-0.53	-0.11
MOS3	-0.78	-0.84	MS18	-0.81	-0.53
MOS4	-1.03	-0.84	MS19	-0.63	-0.26
MOS5	-1.65	-0.47	MS20	-0.72	-0.58
MOS6	-0.97	-0.37	MS21	-0.31	-0.42
MOS7	-0.63	-0.53	MS22	-0.38	0.00
MOS8	-0.50	-0.47	MS23	-0.50	-0.26
MOS9	-0.47	-0.90	MS24	-0.31	0.00
MOS10	-0.72	-0.58	MS25	-0.34	-0.26
MOS11	-0.97	-0.74	MS26	-0.28	+0.05
MOS12	-1.13	-0.58	MS27	-0.22	-0.21
MOS13	-0.97	-0.58	MS28	-0.44	0.00
MOS14	-1.03	-0.58	MS29	-0.78	-0.05
MOS15	-0.81	-0.16	MS30	-0.84	-0.47
MOS16	-0.94	-0.90	MS31	-0.91	-0.53
MOS17	-0.66	-0.42	MS32	-0.63	-0.37
MOS18	-0.72	-0.90	MS33	-0.59	-0.21
MOS19	-0.84	-0.47	MS34	-0.91	-0.53
MOS20	-0.72	+0.05	MS35	-0.44	-0.32
MOS21	-0.72	-0.79	MS36	-0.53	-0.20
MOS22	-1.16	-0.90	MS37	-0.28	-0.11
MOS23	-0.69	-0.53	MS38	-0.72	-0.05
MOS24	-1.09	-0.68	MS39	-0.47	+0.11
MOS25	-0.66	-0.26	MS40	-0.53	-0.26
MOS26	-1.28	-1.05	MS41	-0.50	+0.32
MOS27	-0.84	-0.26	MS42	-0.72	-0.37
MOS28	-1.00	-0.16	MS43	-0.75	-0.21
DV1B	-0.63	-0.16	MS44	-0.47	-0.58
DV2B	-0.75	-0.58	MS45	-0.75	-0.68
DV3B	-0.66	-0.53	MS46	-0.91	+0.47
DV4B	-0.38	-1.11	MS47	-0.31	-0.32
DV5B	-0.91	-0.16	MS48	-0.50	-0.26
DV6B	-1.22	-0.42	MS49	-0.63	-0.16
DV7B	-0.78	-0.74	MS50	-0.47	-0.37
MS1	-1.06	-1.16	MS51	-0.44	-0.21
MS2	-0.44	-0.42	MS52	-0.31	-0.05
MS3	-1.00	-0.79	MS53	-0.25	+0.16
MS4	-0.28	-0.32	MS54	-0.66	-0.37
MS5	-0.69	-0.21	MS55	-0.66	-0.53
MS6	-0.53	-0.21	MS56	-0.75	-0.32
MS7	-0.66	+0.74	MS57	-0.91	-0.26
MS8	-0.56	-0.58	MS58	-0.81	-0.74
MS9	-1.22	-0.11	MS59	-0.91	-0.58
MS10	-1.06	-0.79	MS60	-0.34	-0.16
MS11	-1.19	-0.90	MS61	-0.53	-0.74
MS12	-0.25	-0.05	MS62	-0.50	0.00
MS13	-1.03	-0.16	MS63	-0.69	-0.68
MS14	-0.78	-0.58	MS64	-0.94	-0.53
MS15	-0.94	-0.84	MS65	-0.88	-0.42
MS16	-1.03	-0.74	MS66	-1.06	-1.11

NOTES: 1)Moscar Top (0.5km,360m.asl) to Attercliffe (26km, 40m.asl)
2) Moscar Top (0.5km, 360m.asl) to Rivelin Valley (6.3km,170m.asl)

Photo 5.1: Penistone Road (A61) Near Herries Road (A6102)

Photo 5.2: Don Valley Stadium, Attercliffe Road (A6178)

Photo 5.3: Railway Bridge Over Furnival Road (B6073)

Photo 5.4: South Yorkshire Police HQ and Whitbread Brewery, Bridge Street

Photo 5.5: Steelworks, Brightside Lane (A6109)

Photo 5.6: City Centre, Commercial Street

Photo 5.7: Sheffield Parkway (A57) Crossing Over Railway Line

Photo 5.8: Lady's Bridge Over River Don

Photo 5.9: Blonk Street Bridge Over River Don

CHAPTER 6

Figure 6.1: Plot of Standard Deviation (SD) Against Difference (D)

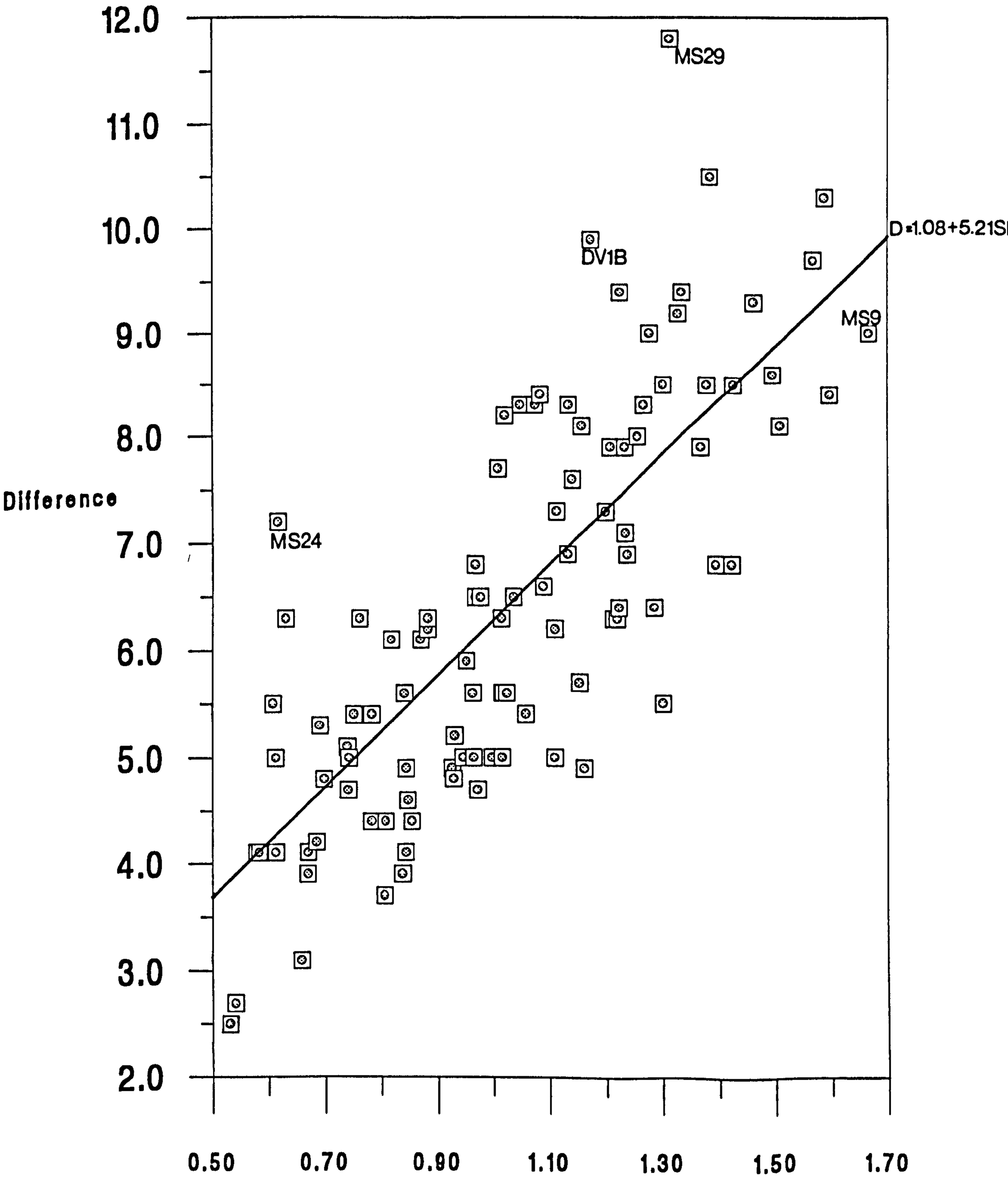


Figure 6.2: Plot of Standard Deviation Against Cloud Start

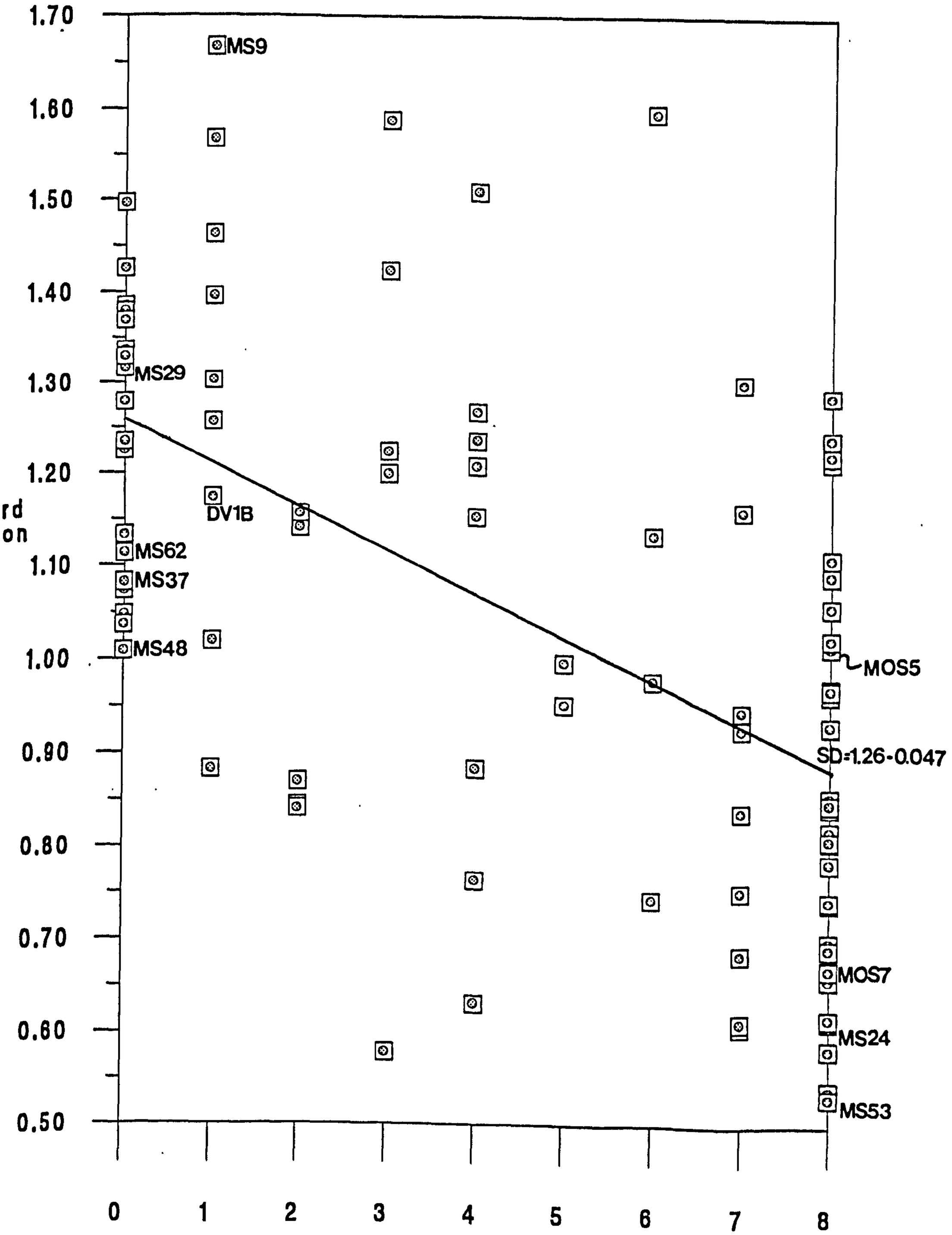


Figure 6.3: Plot of D Against Cloud Start

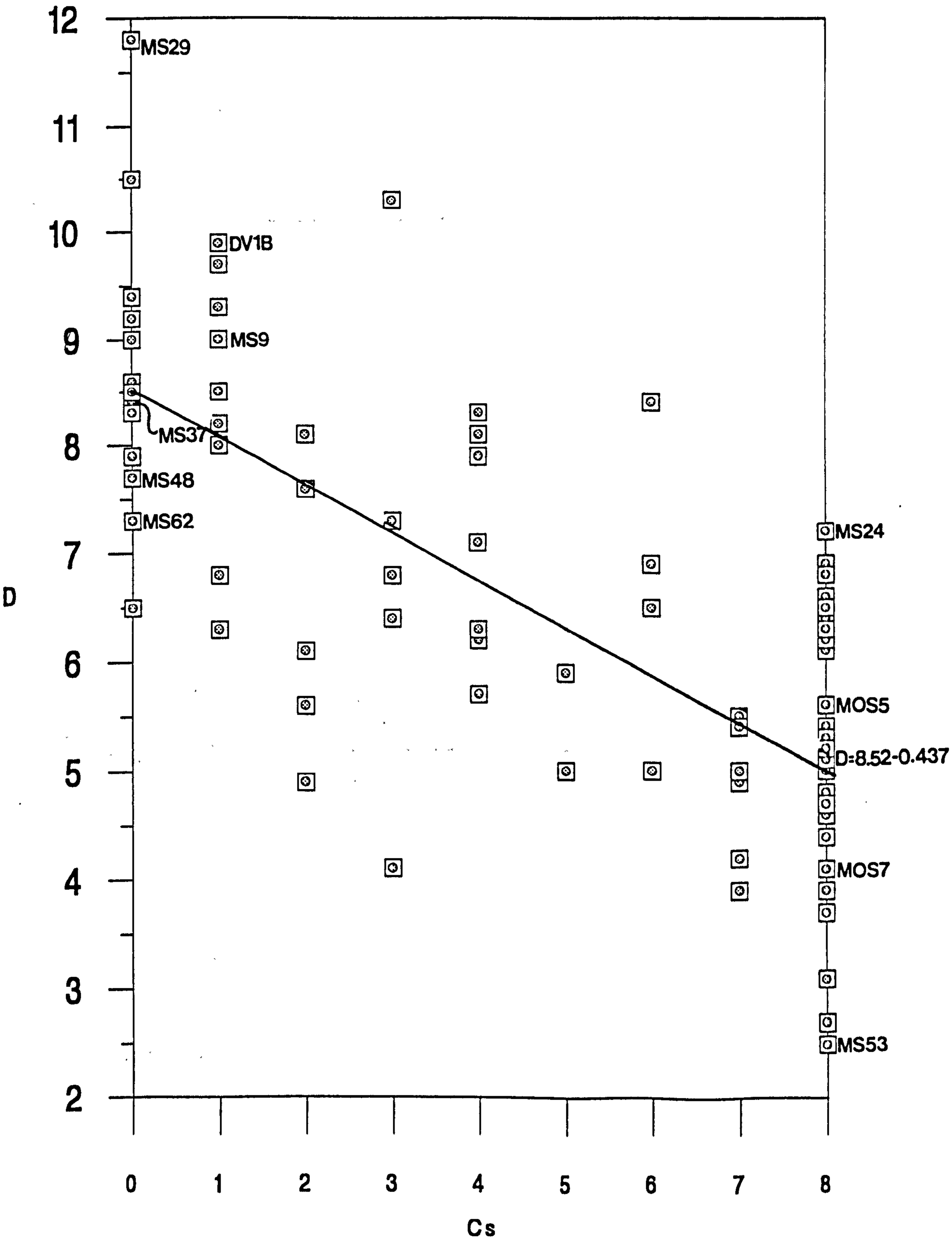
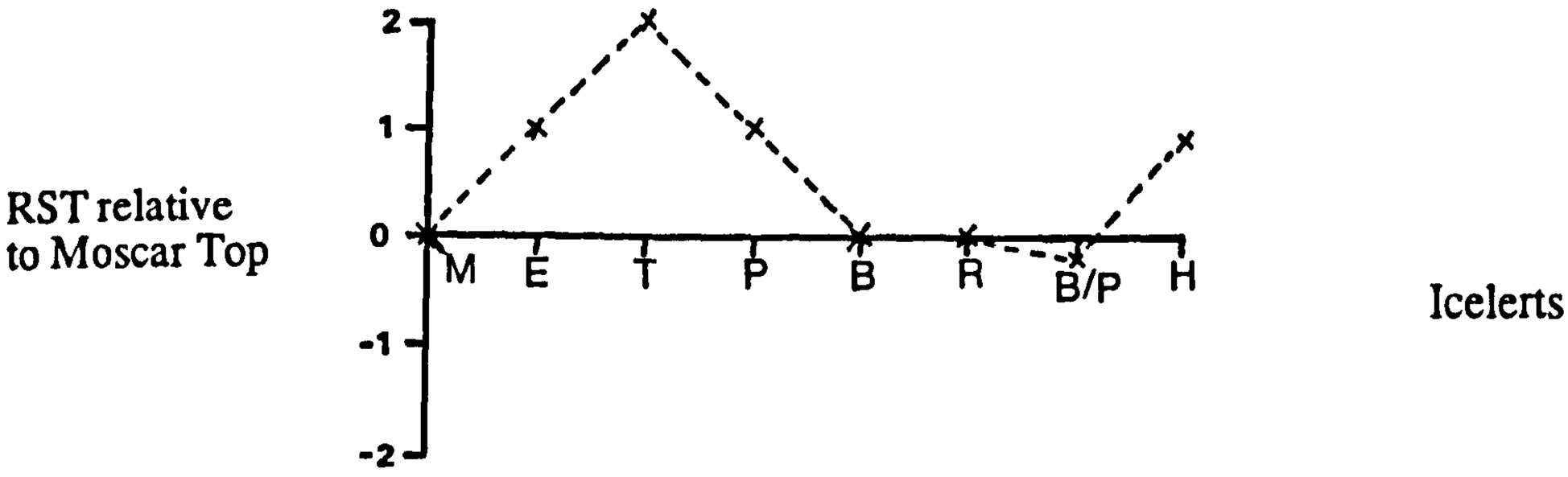
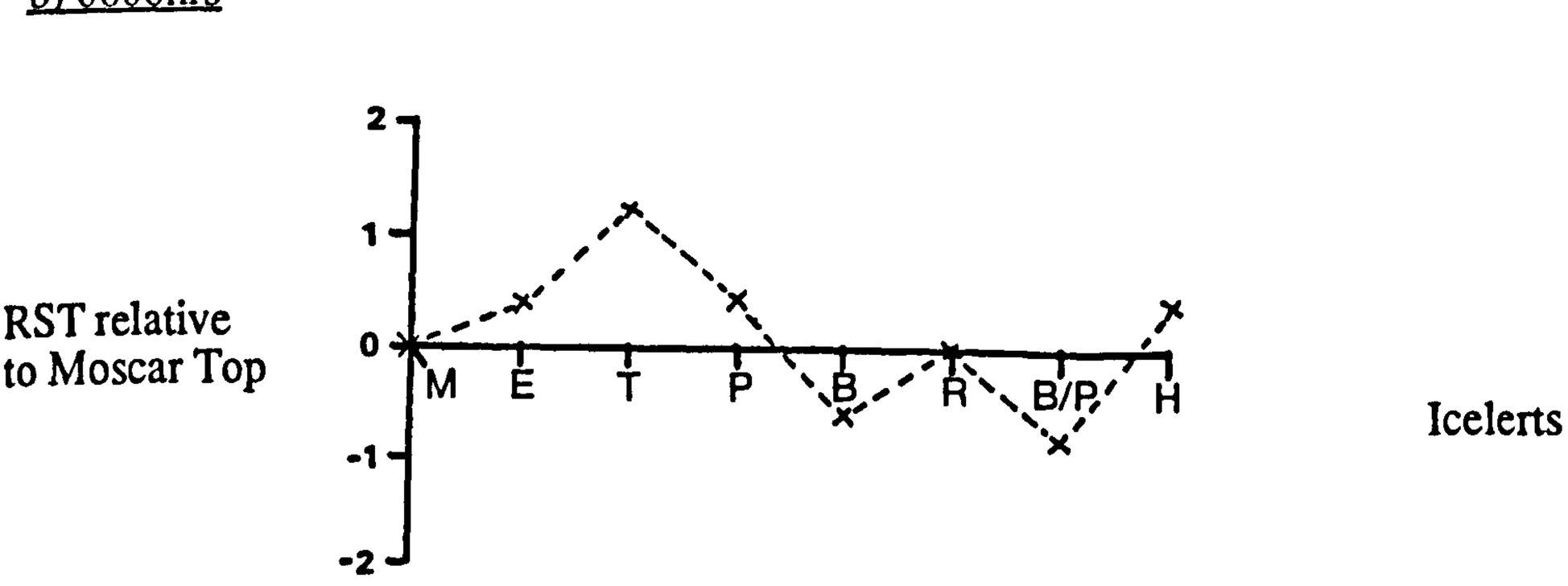


Figure 6.4: Icelert RSTs Relative to Moscar Top
During Night of 13/14.1.92

a) 0000hrs

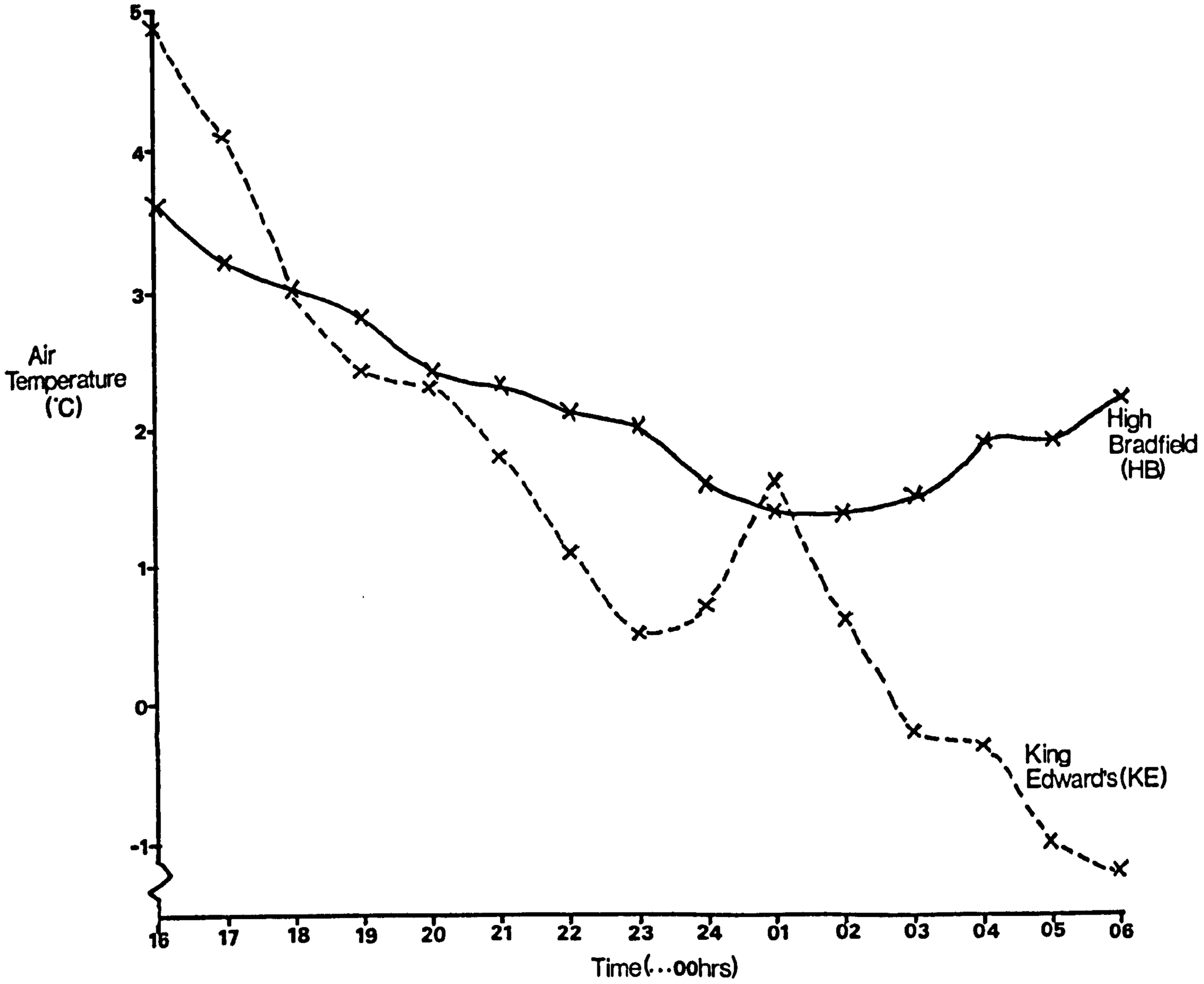


b) 0600hrs



Icelerts: M = Moscar Top
E = Elliott Lane
T = Tinsley
P = Prince of Wales Road
B = Birley Moor
R = Ringinglow
B/P = Bradway/Prospect Road
H = Hillfoot

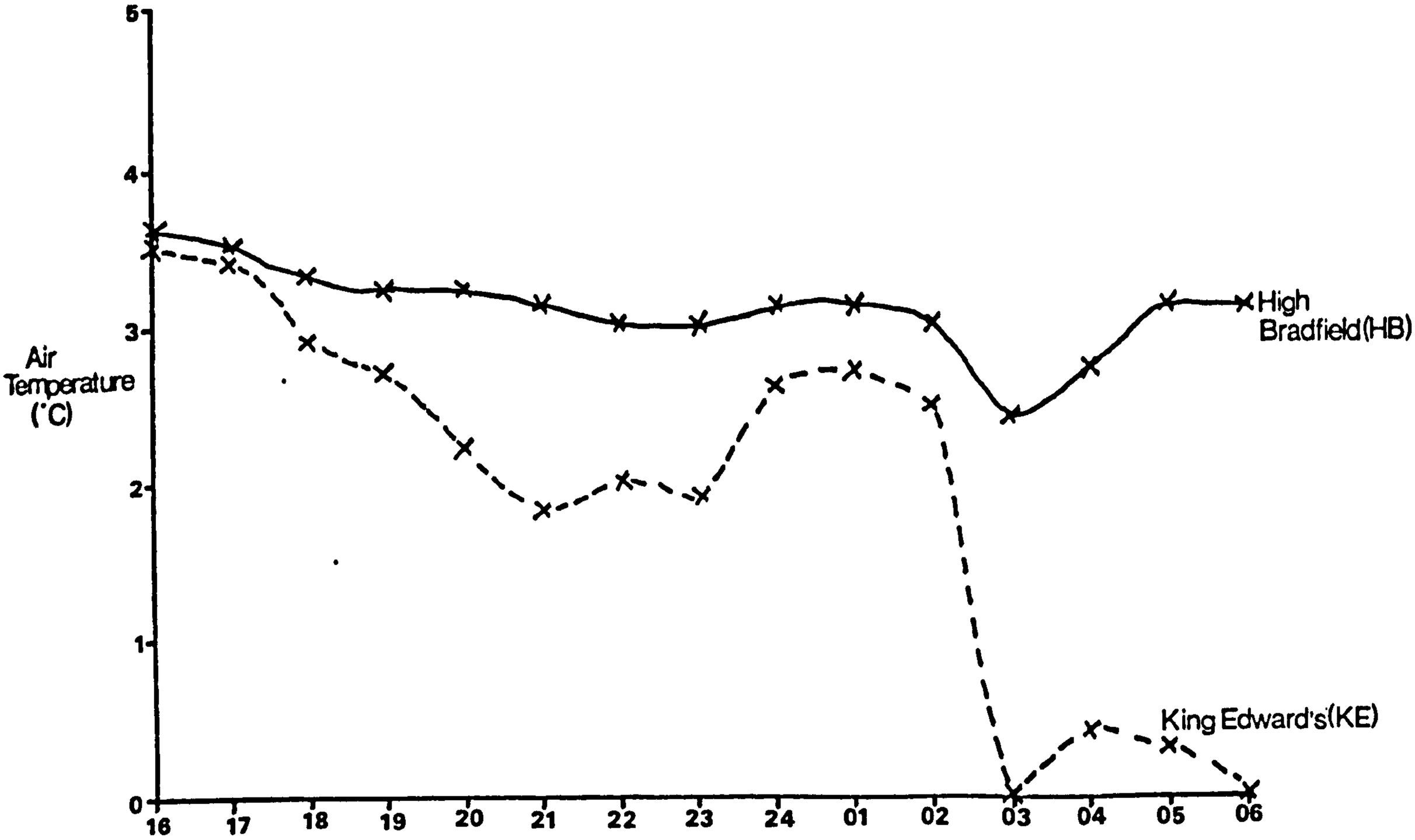
Figure 6.5: Thermograph Traces During Night Of 13/14.1.92



Cooling rates (^{o}C/hour):

	HB	KE
2100-0000hrs	-0.23	-0.37
0000-0300hrs	-0.03	-0.30
0300-0600hrs	+0.23	-0.33
2100-0600hrs	-0.01	-0.33

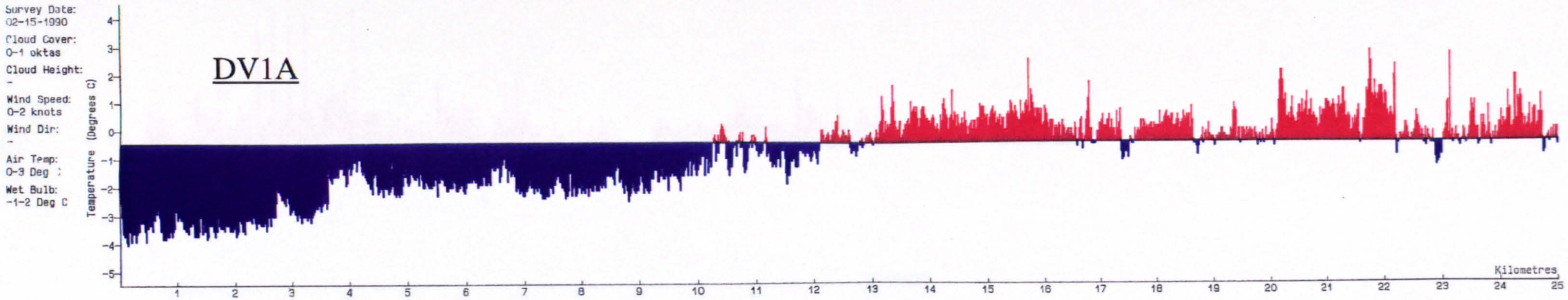
Figure 6.6: Thermograph Traces During Night Of 16/17.1.92



Cooling rates (^{0}C/hour):

	HB	KE
2100-0000hrs	+0.03	+0.27
0000-0300hrs	-0.13	-0.87
0300-0600hrs	+0.20	0.00
2100-0600hrs	+0.03	-0.20

Figure 6.7: Fingerprints of Runs Made Along Route 1 During Night of 15/16.2.90 (continued overleaf)



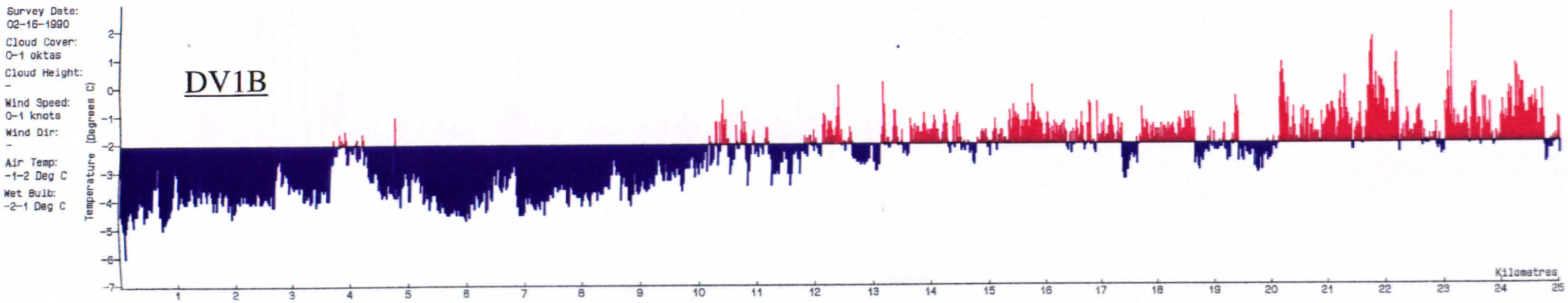
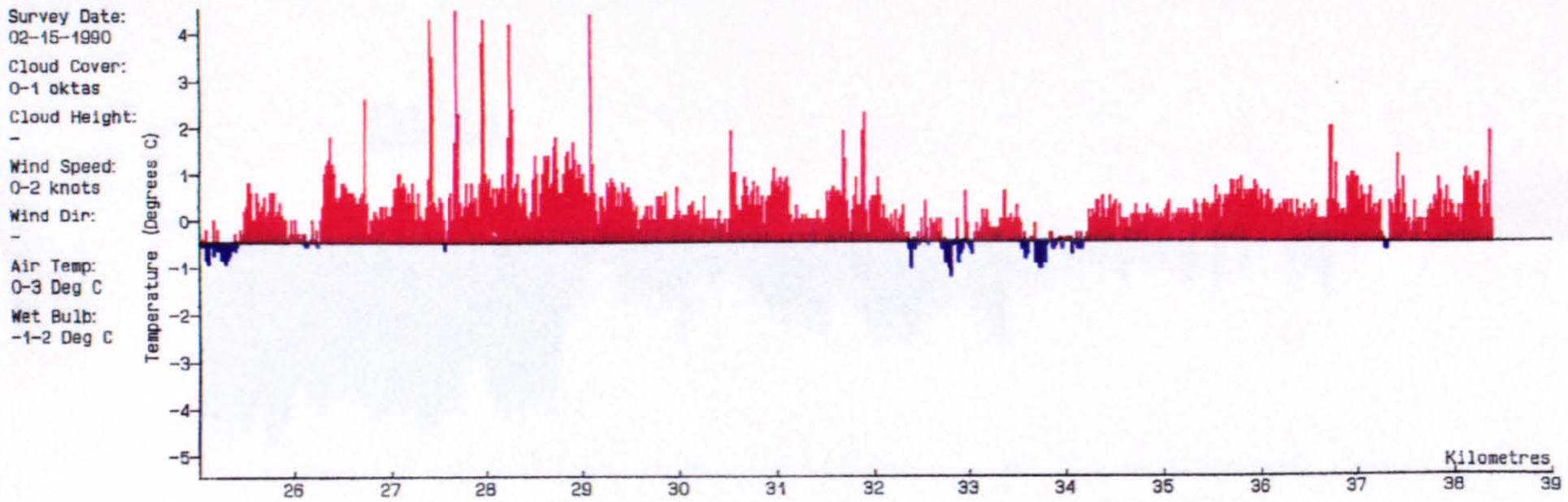
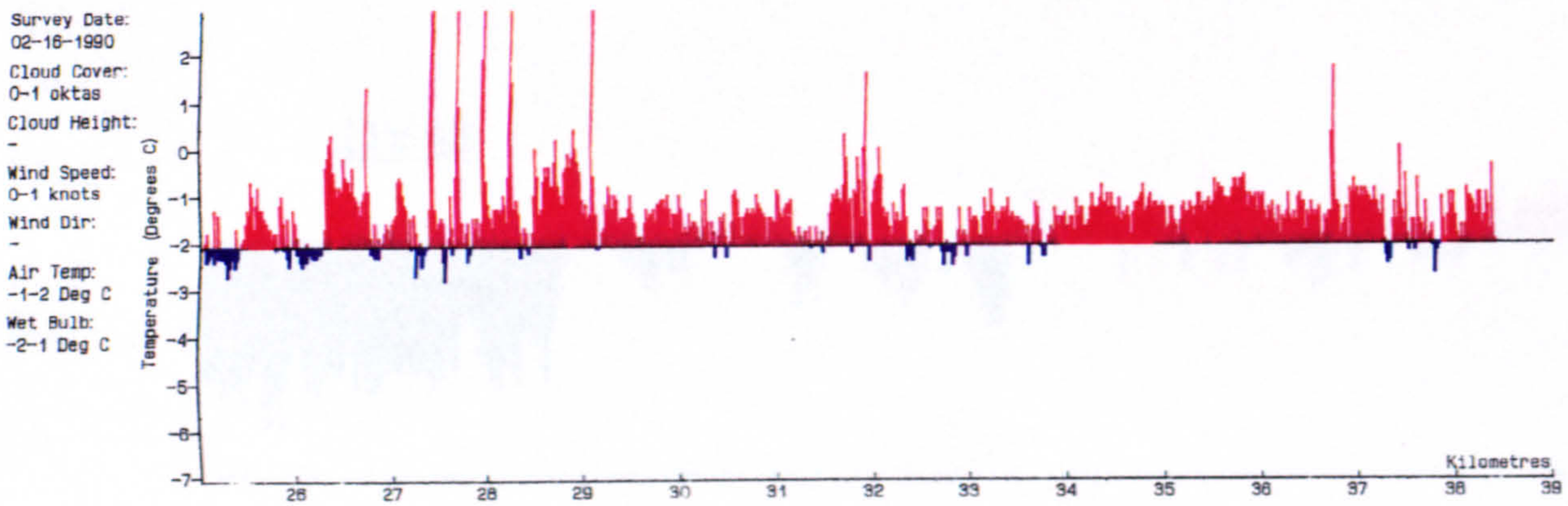


Figure 6.7: Fingerprints of Runs Made Along Route 1 During Night of 15/16.2.90 (continued)

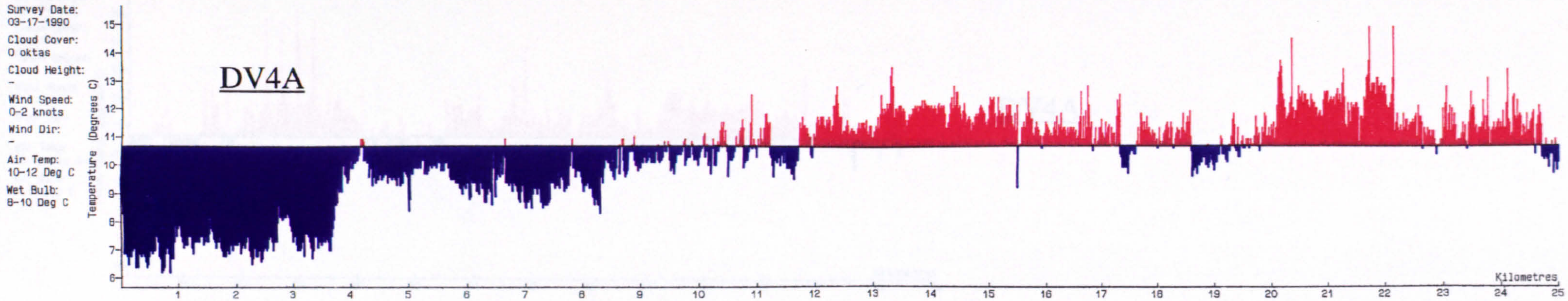


DV1A



DV1B

Figure 6.8: Fingerprints of Runs Made Along Route 1 During Night of 17/18.3.90 (continued overleaf)



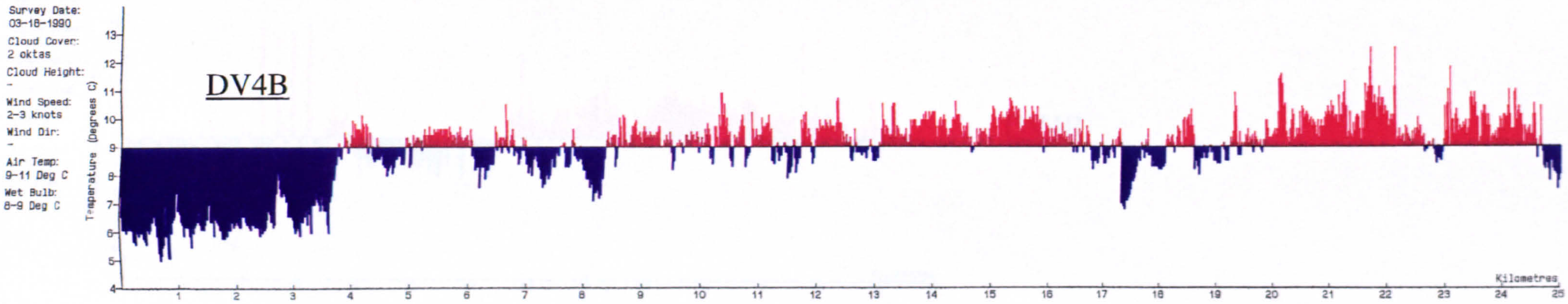
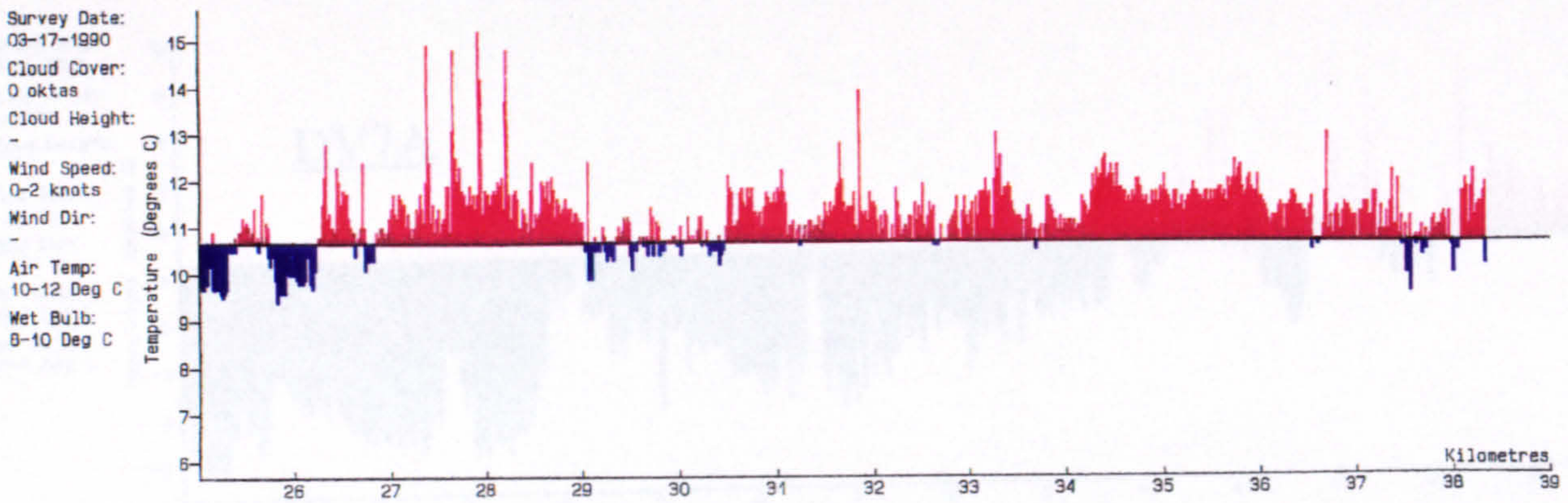
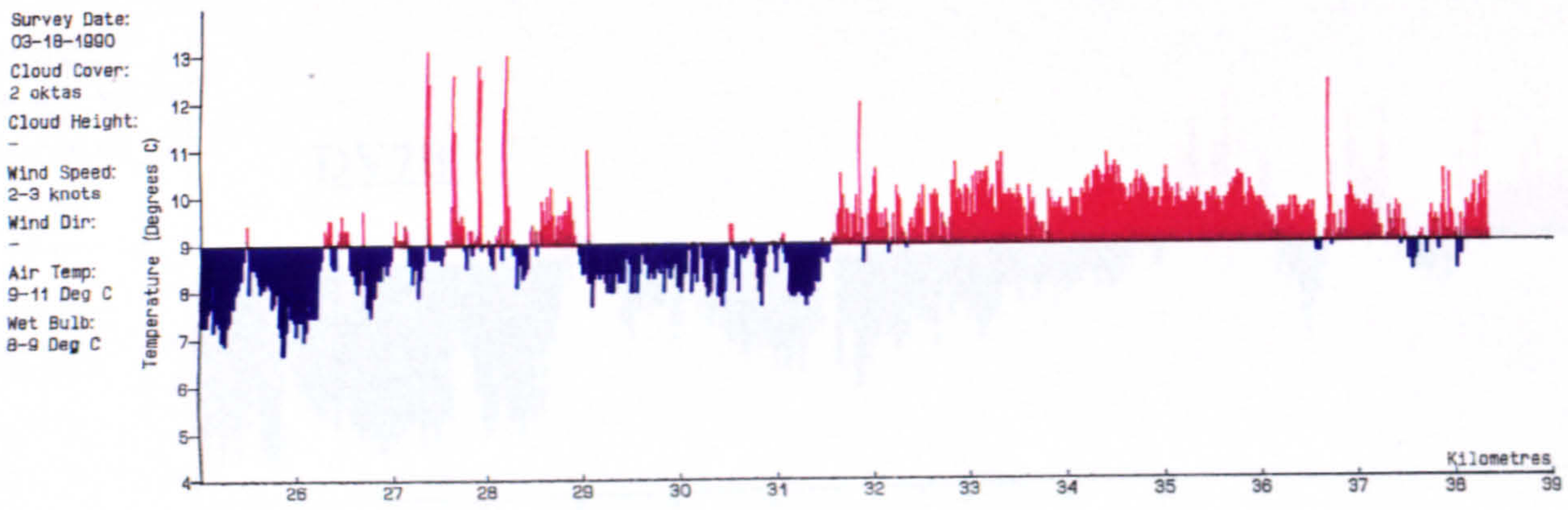


Figure 6.8: Fingerprints of Runs Made Along Route 1 During Night of 17/18.3.90 (continued)

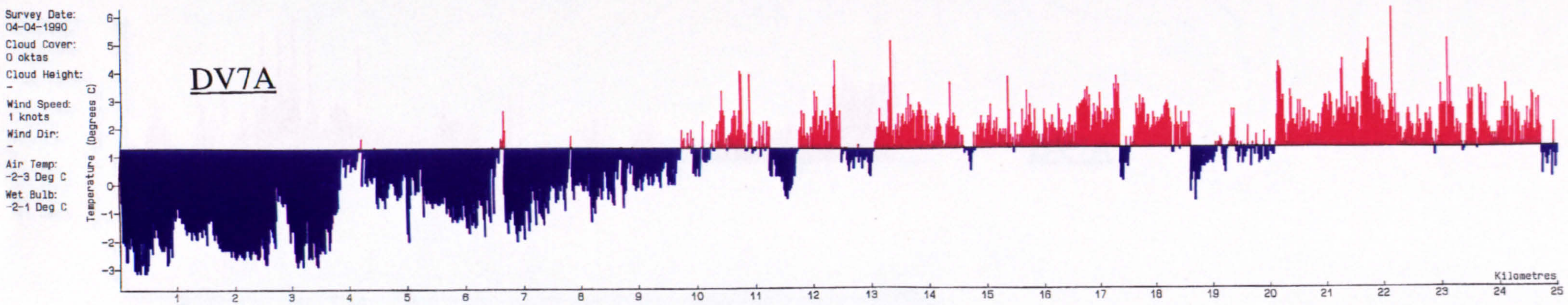


DV4A



DV4B

Figure 6.9: Fingerprints of Runs Made Along Route 1 During Night of 4/5.4.90 (continued overleaf)



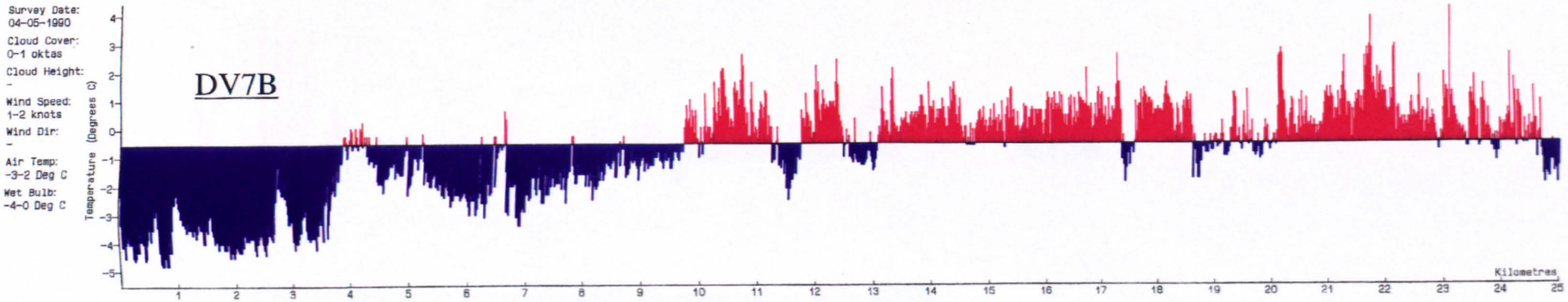
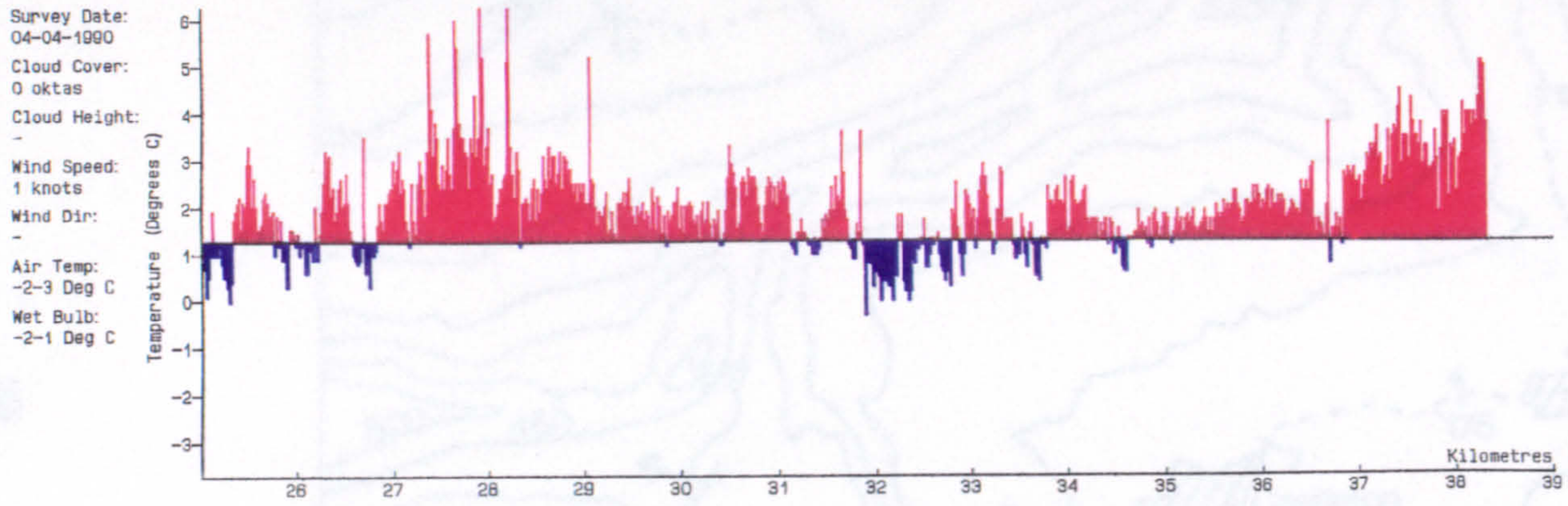
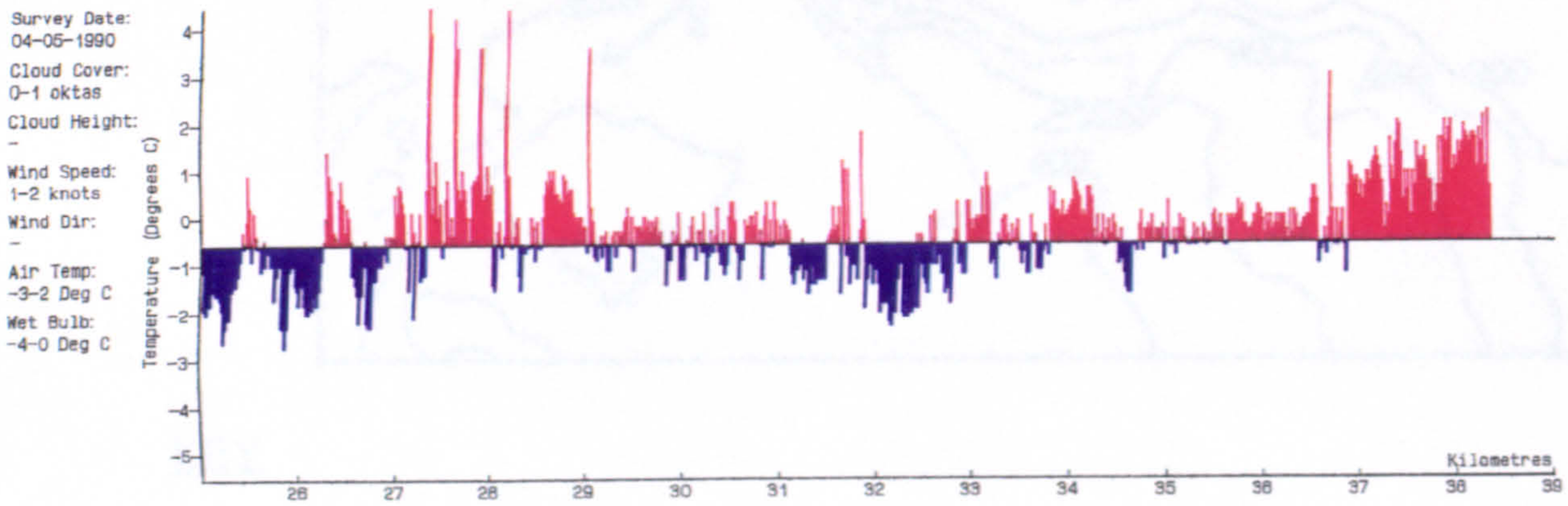


Figure 6.9: Fingerprints of Runs Made Along Route 1 During Night of 4/5.4.90 (continued)

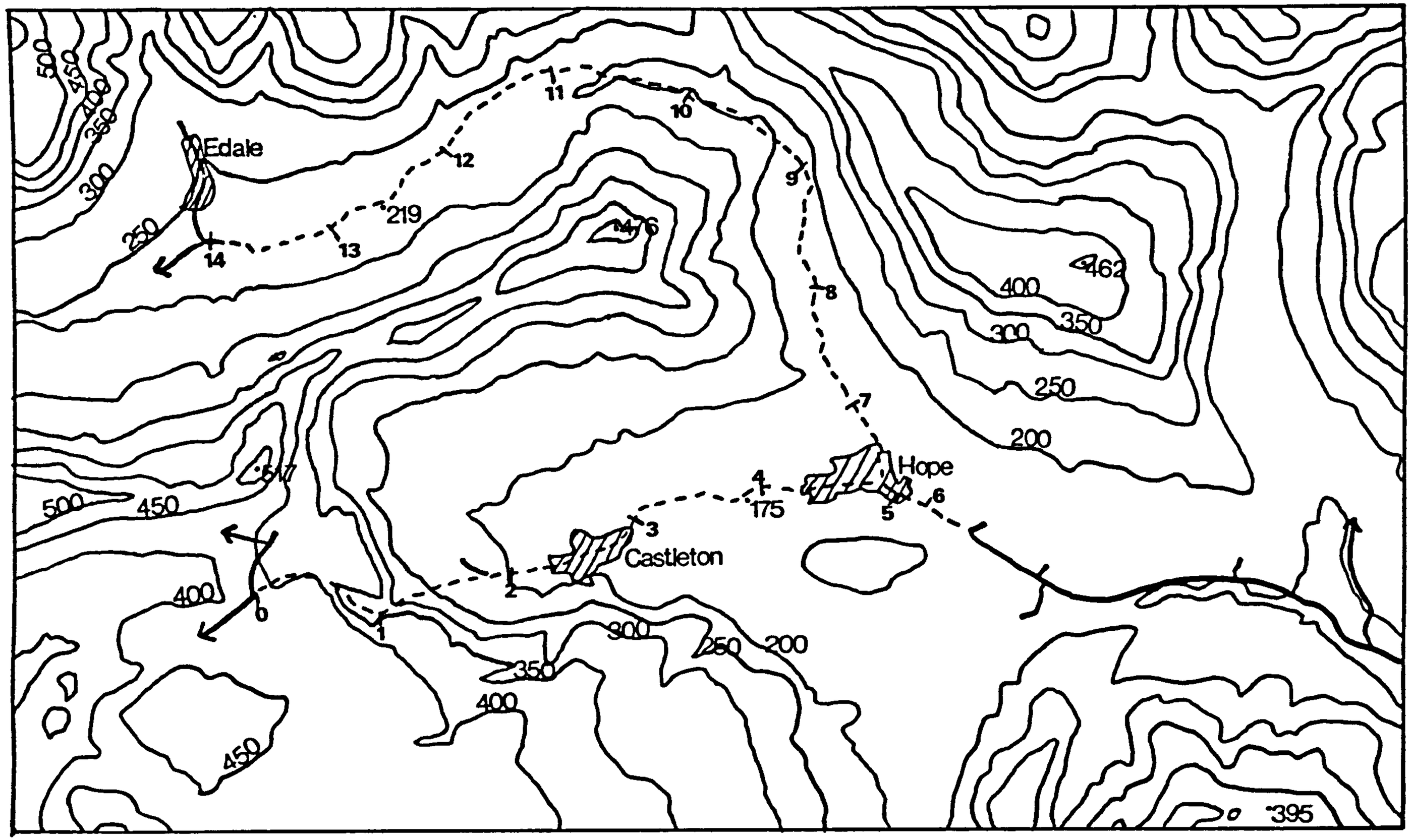


DV7A



DV7B

Figure 6.10: Altitude Variation in the Hope and Edale Valleys, Derbyshire

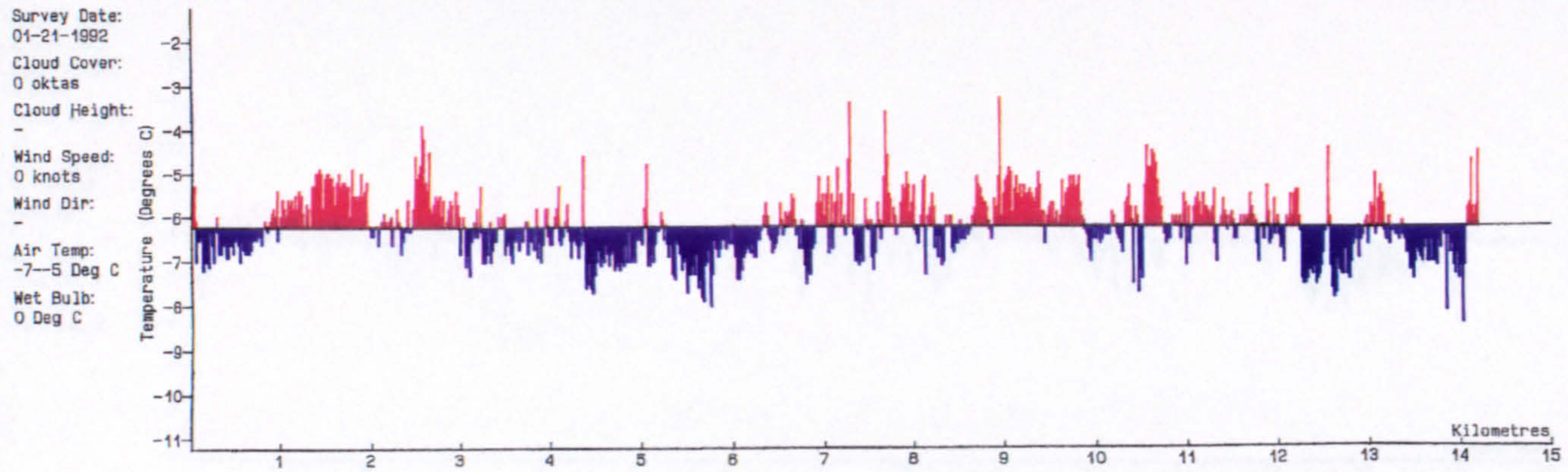


KEY

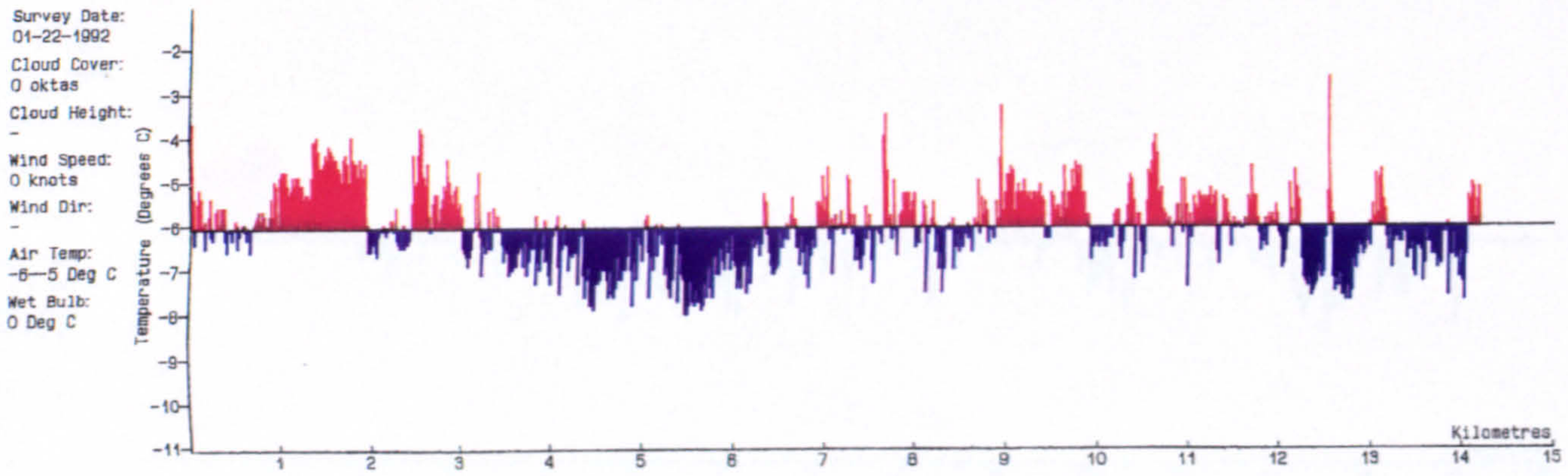
SCALE 0 1 2km

contours (m.asl)
built-up areas
·395 spot heights (m.asl)
main roads
mapping route with distance (km) indicated
1

Figure 6.11: Fingerprints of Runs Made in Derbyshire During Night of 21/22.1.92

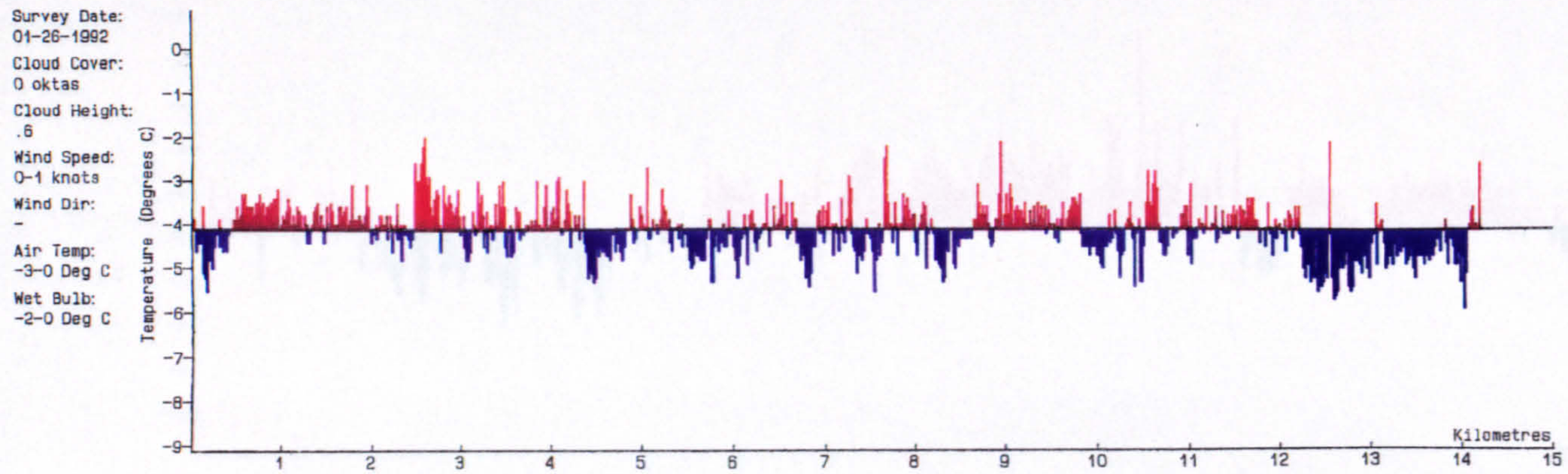


DB2A

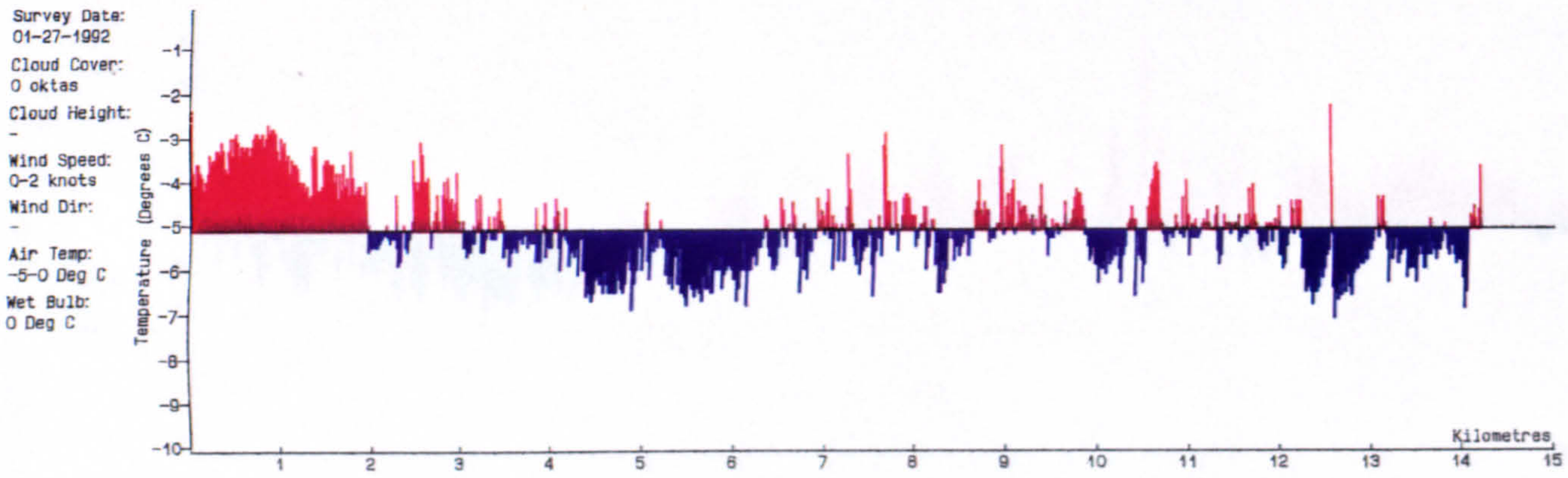


DB2B

Figure 6.12: Fingerprints of Runs Made in Derbyshire During Night of 26/27.1.92



DB3A



DB3B

Other Examples of Extreme Fingerprints of Route2

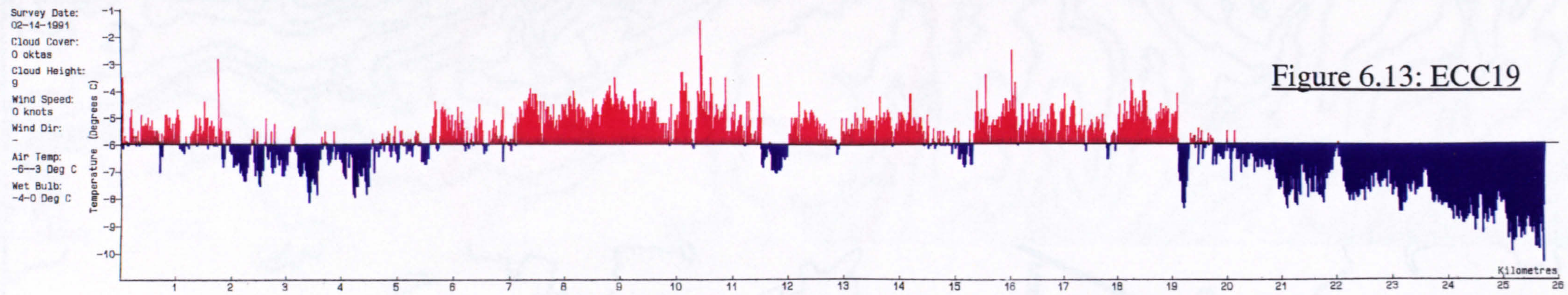


Figure 6.13: ECC19

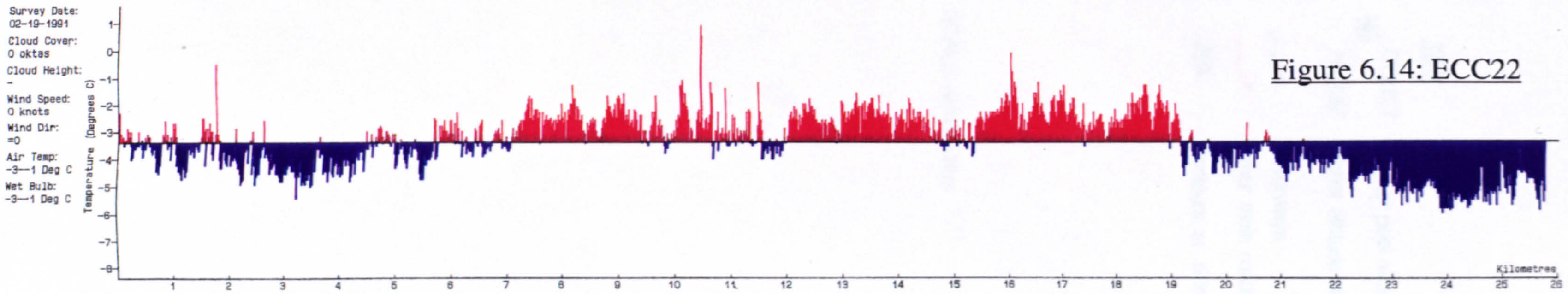


Figure 6.14: ECC22

Figure 6.15: Location of Cold Air (RST) Pool Sites

KEY

C1,2,6,7 Cold air pool sites routes 1,2,6,7

H1,2,6,7 Higher altitude sites routes 1,2,6,7

Motorways

Other main roads

250 Contours at 50m intervals

SCALE: 10mm = 1km

Figure 6.16 : Plot of Wind Speed Against Cold Air (RST) Pool (extreme runs route 1)

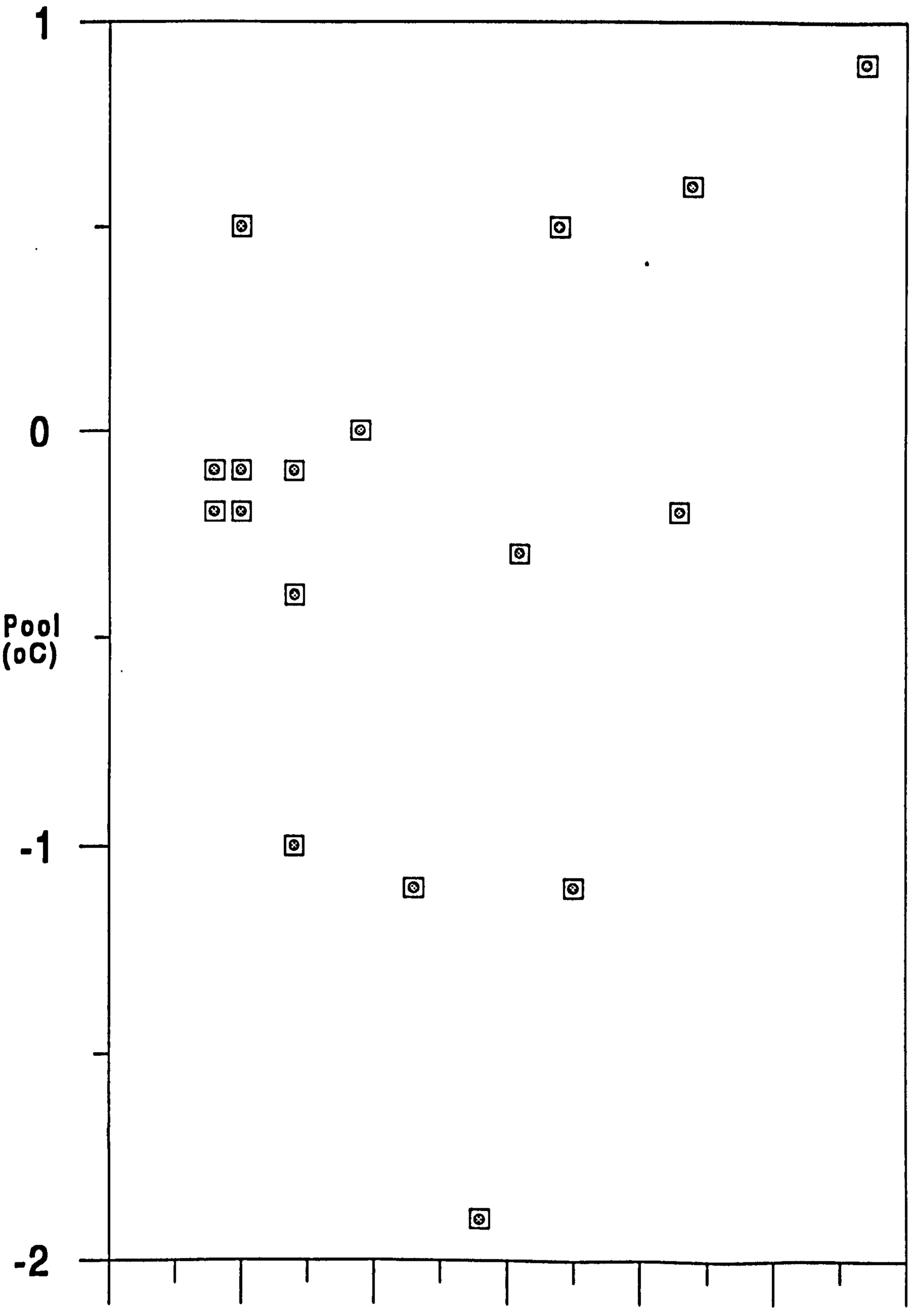
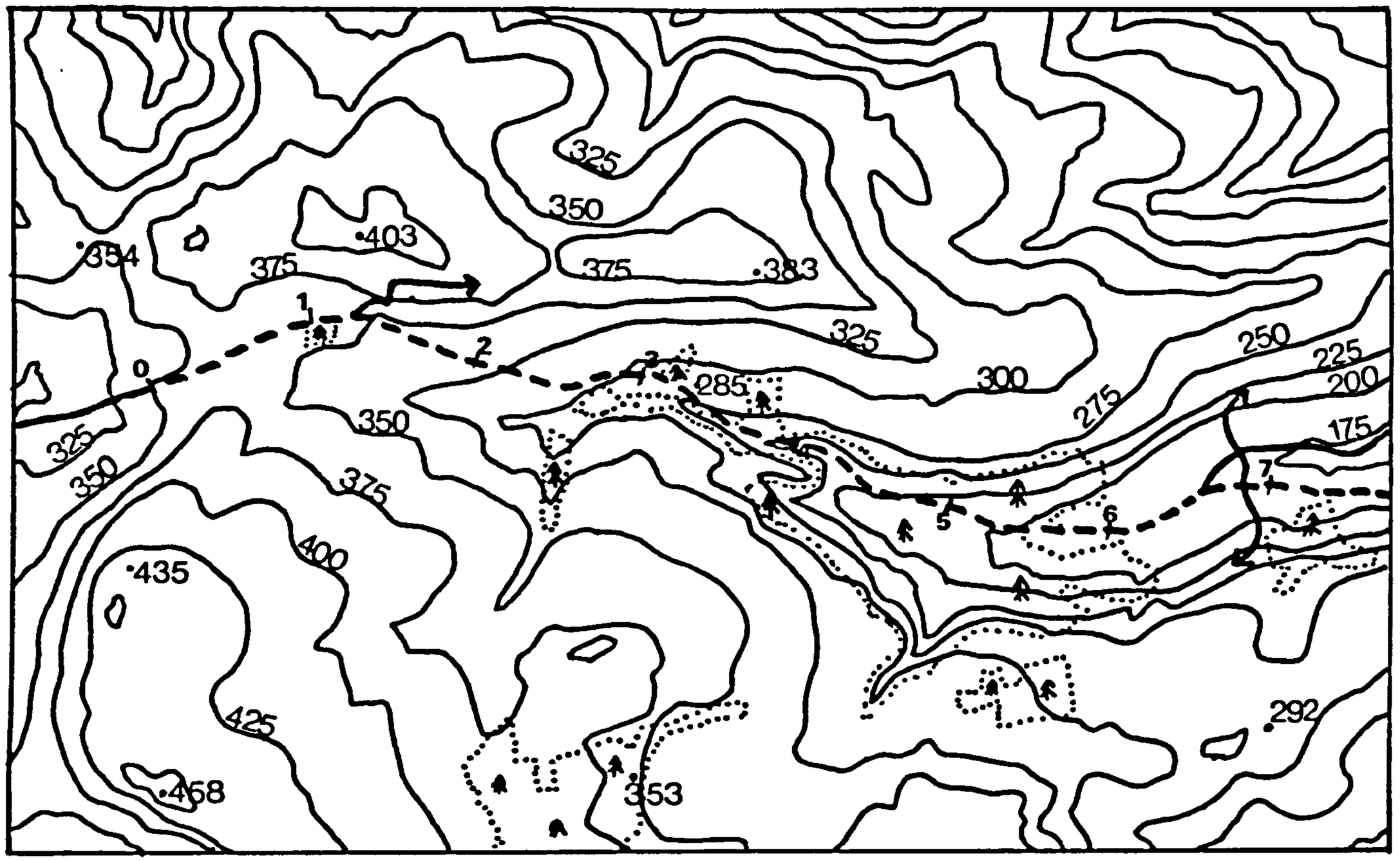


Figure 6.17: Altitude Variation Near Start of Route 1



KEY

375 contours (m.asl)
woodland
·354 spot heights (m.asl)
main roads
mapping route with distance (km) indicated
1

SCALE

0 1 2km

Other Examples of Extreme Fingerprints of Route 1 (continued overleaf)

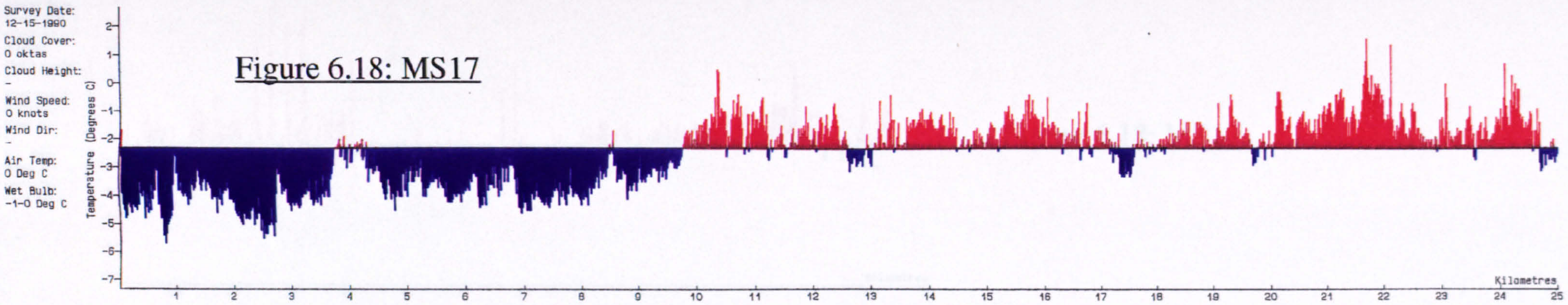


Figure 6.18: MS17

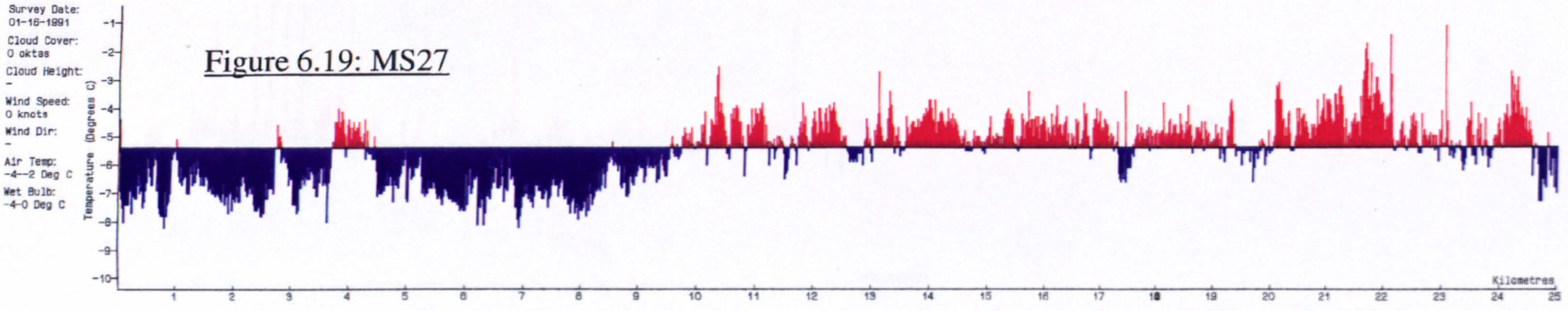


Figure 6.19: MS27

Other Examples of Extreme Fingerprints of Route 1 (continued)

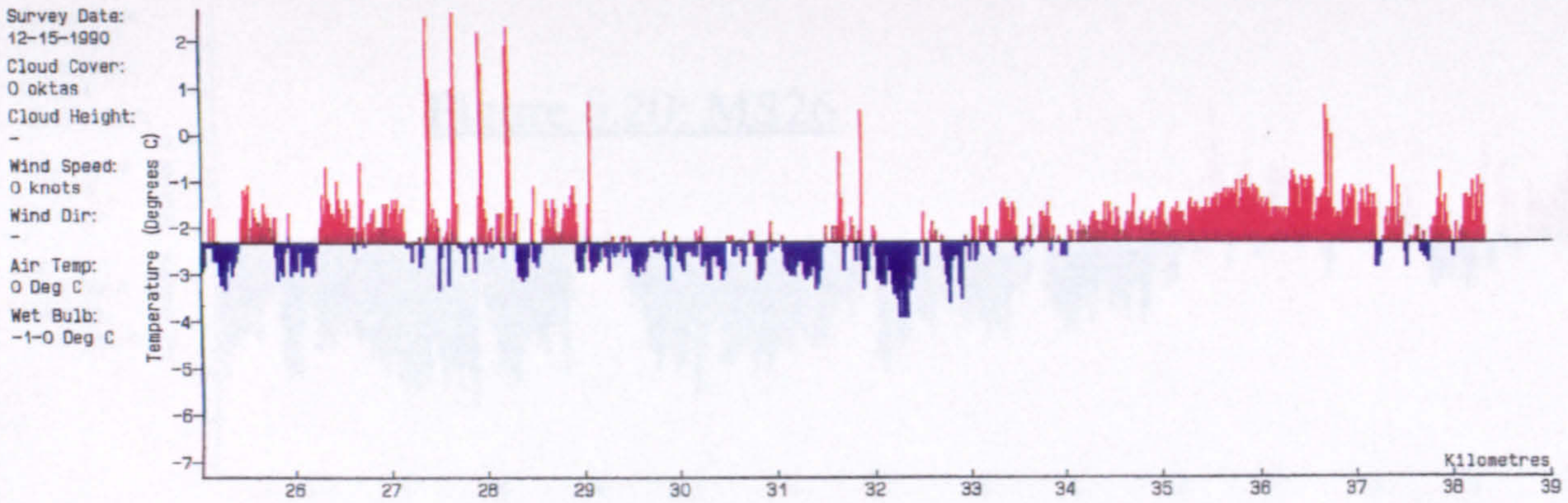


Figure 6.18: MS17

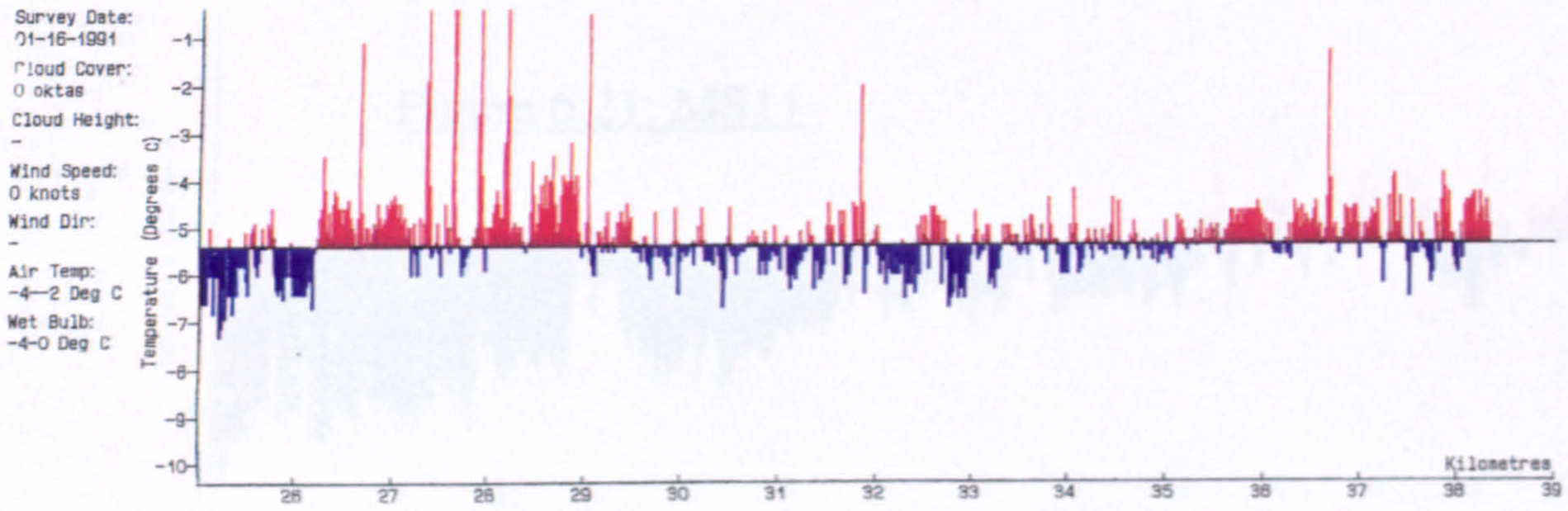


Figure 6.19: MS27

Other Examples of Extreme Fingerprints of Route 1 (continued overleaf)

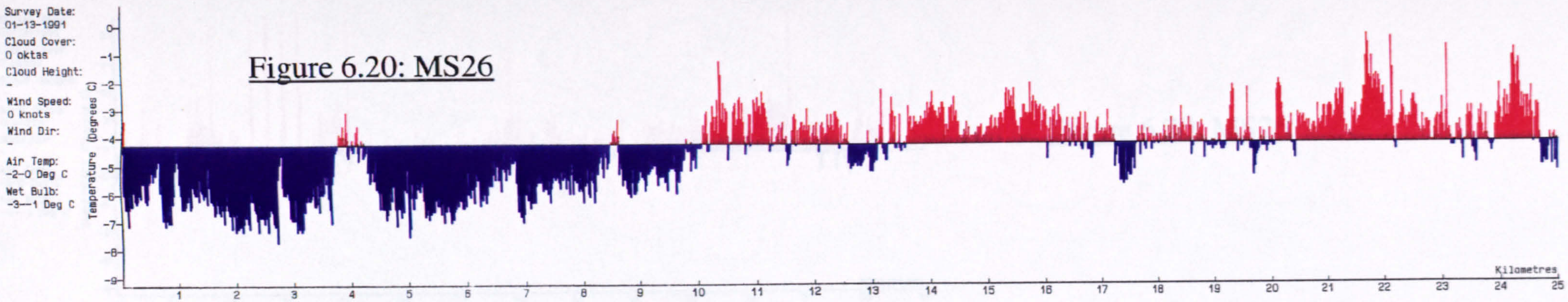


Figure 6.20: MS26

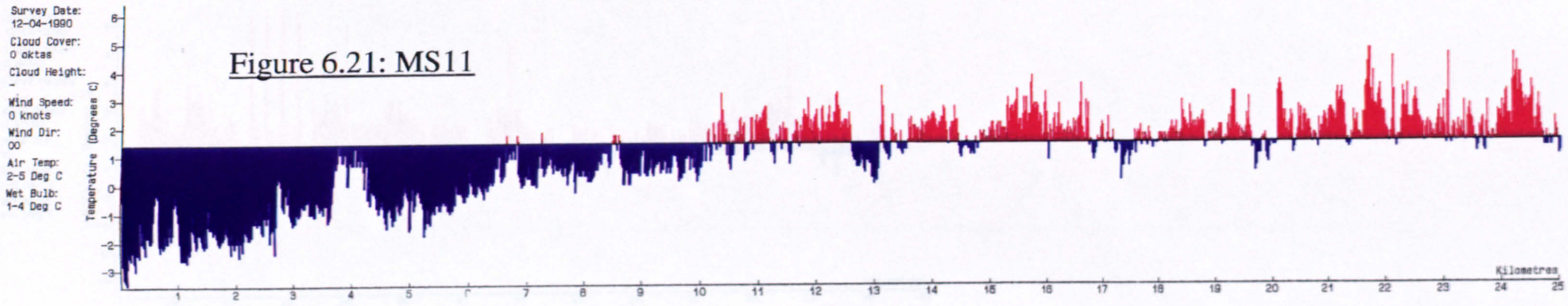


Figure 6.21: MS11

Other Examples of Extreme Fingerprints of Route 1 (continued)

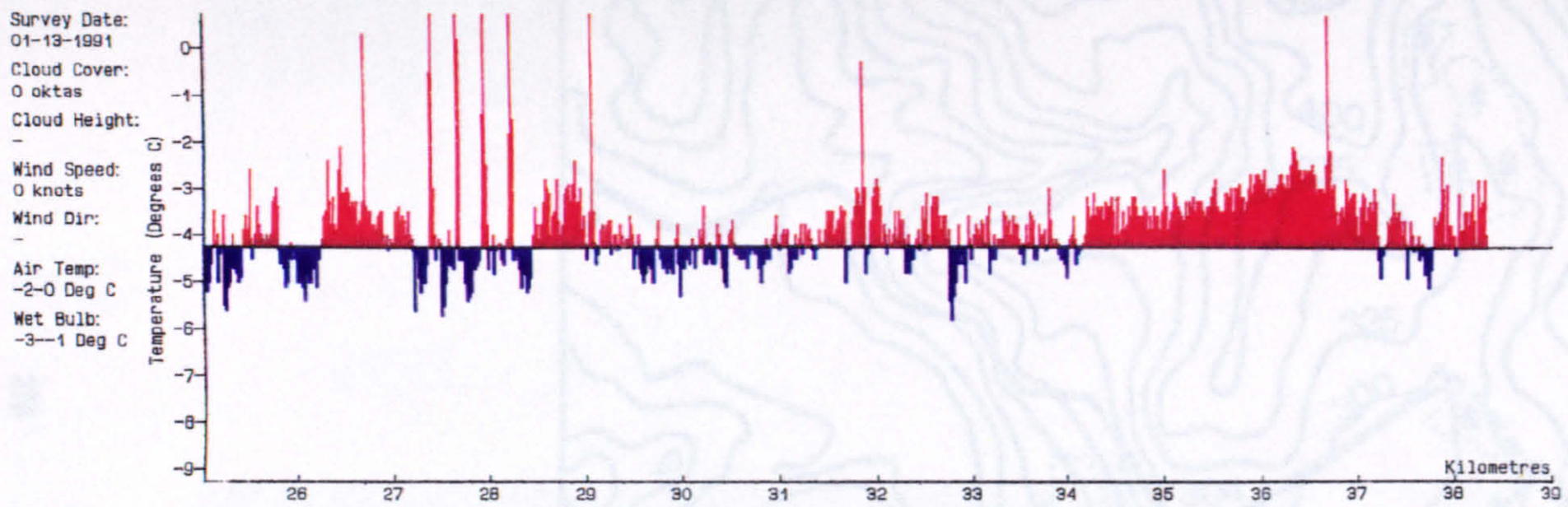


Figure 6.20: MS26

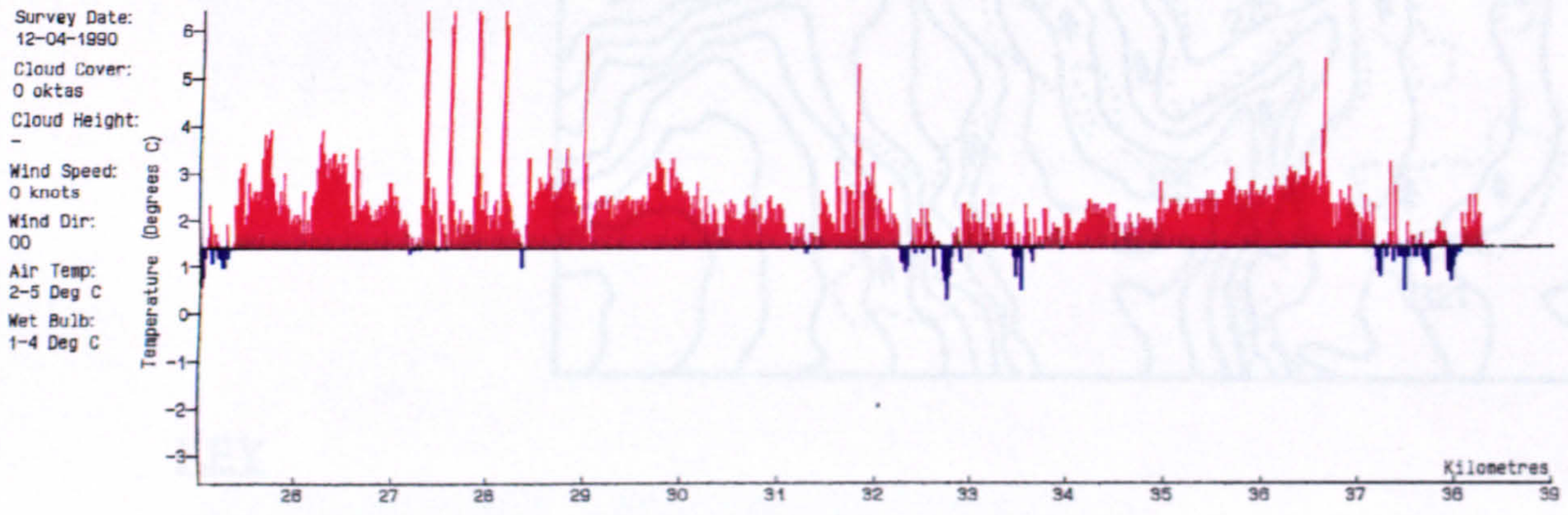
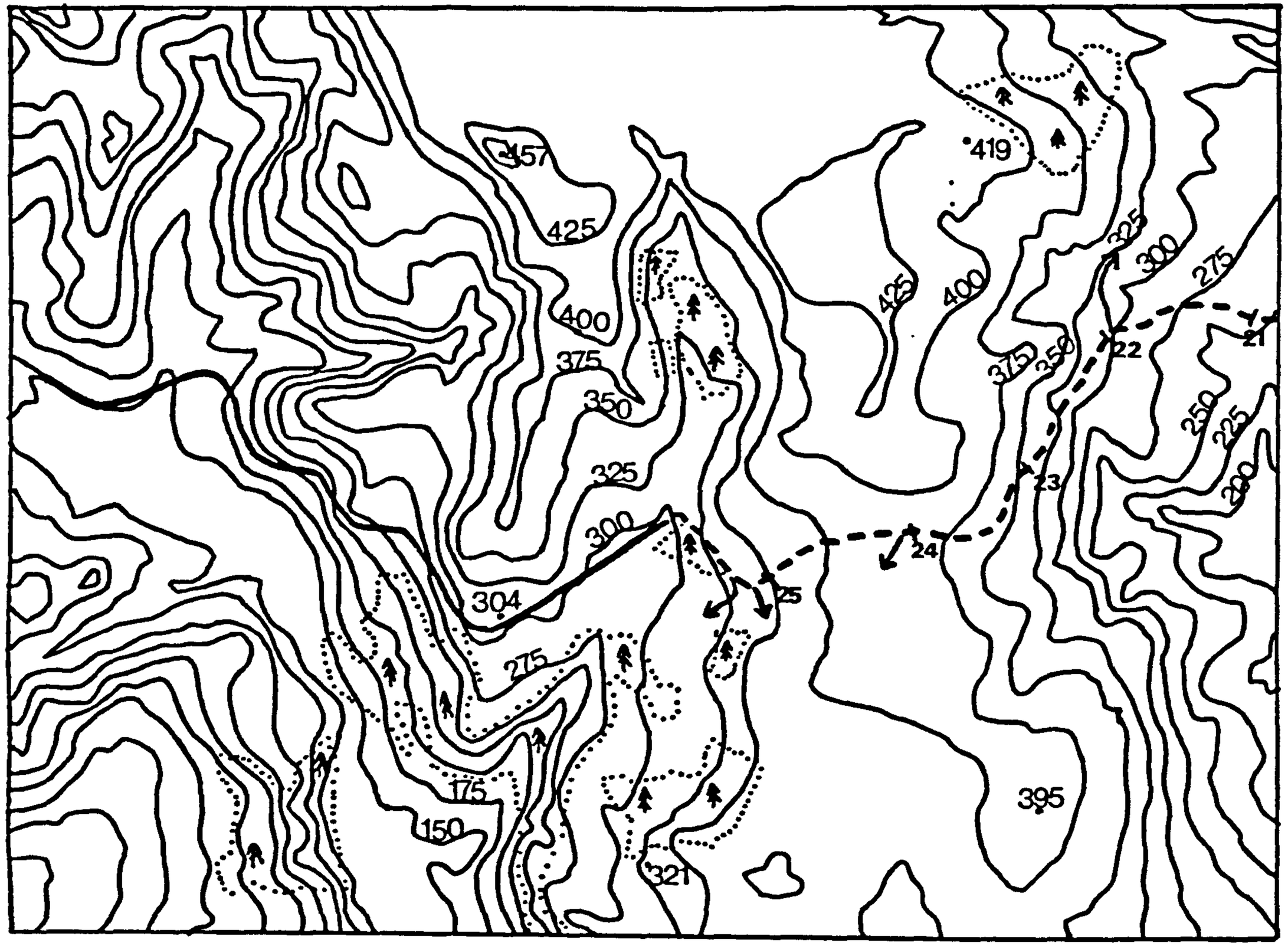


Figure 6.22 : Altitude Variation Around Burbage Valley Near End of Route 2



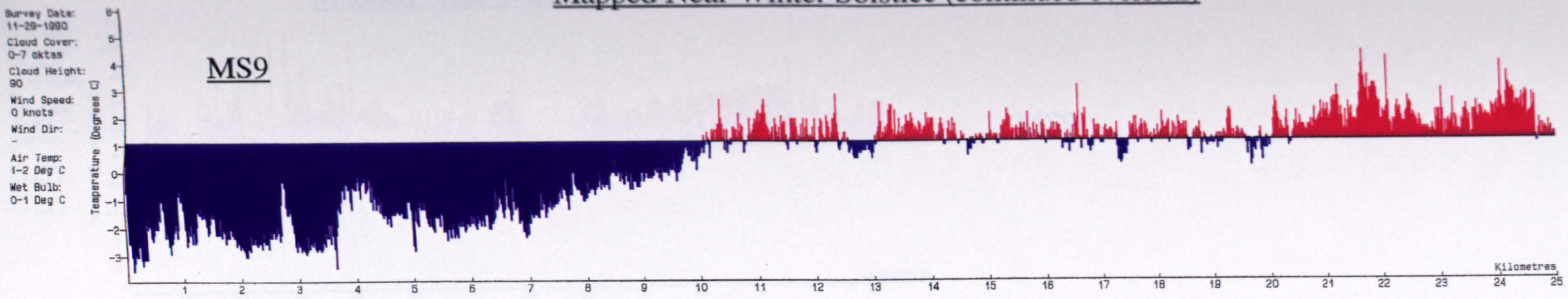
KEY

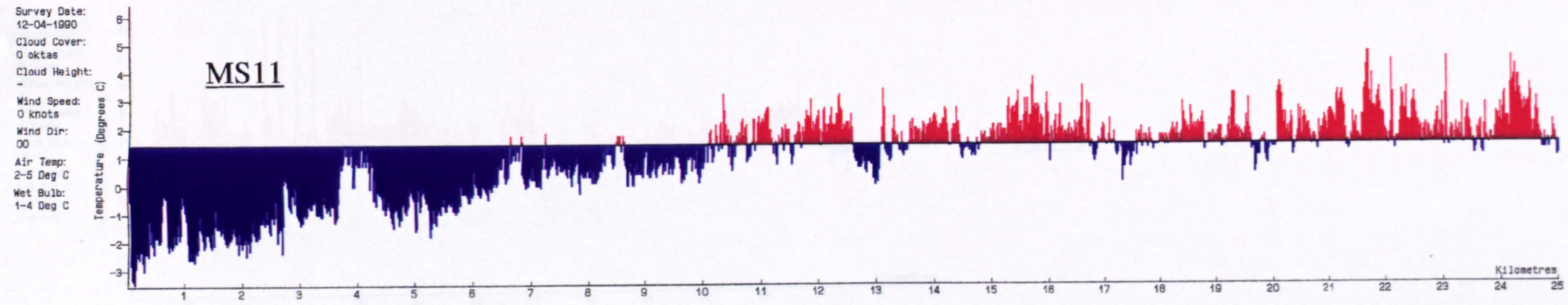
375 contours (m.asl)
woodland
•419 spot heights (m.asl)
main roads
mapping route with distance (km) indicated
1

SCALE

0 1 2km

Figure 6.23: Extreme Fingerprints of Route 1 Mapped Near Winter Solstice (continued overleaf)





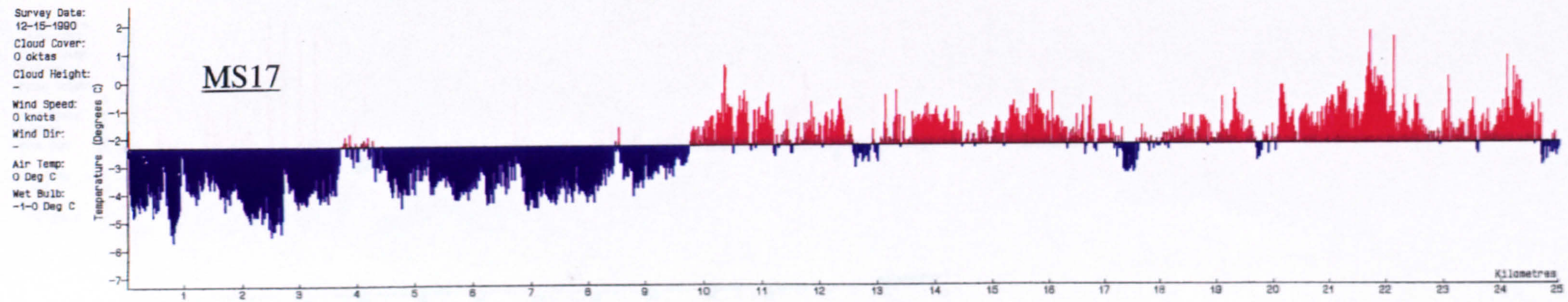
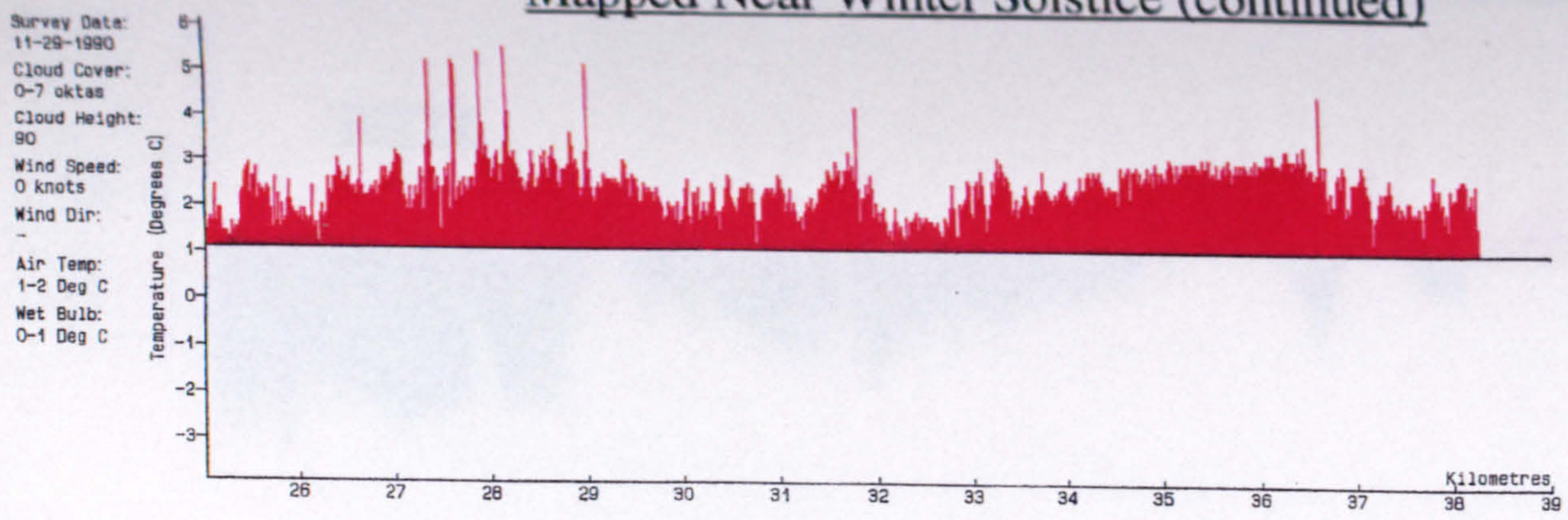
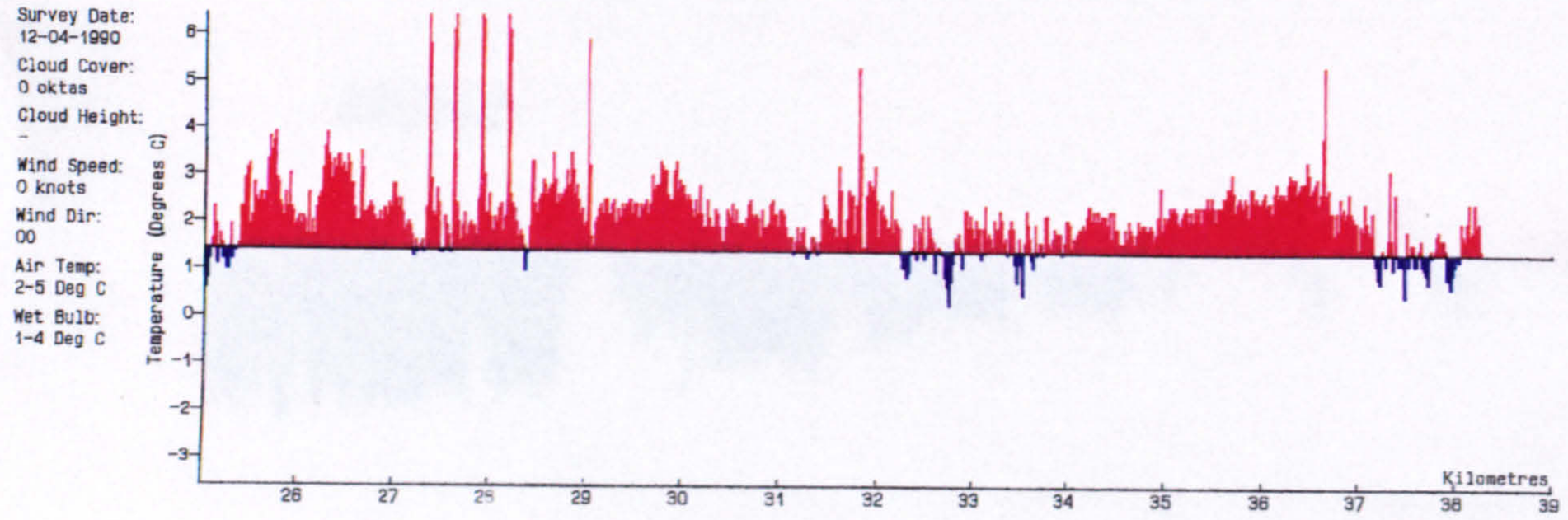


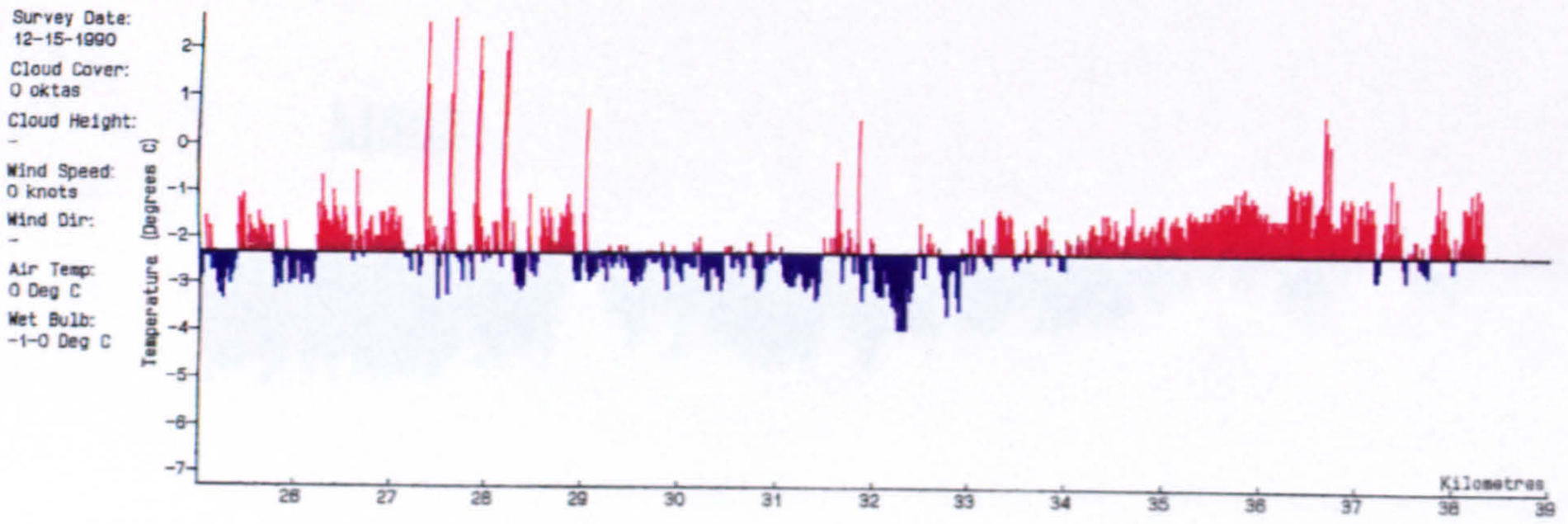
Figure 6.23: Extreme Fingerprints of Route 1 Mapped Near Winter Solstice (continued)



MS9

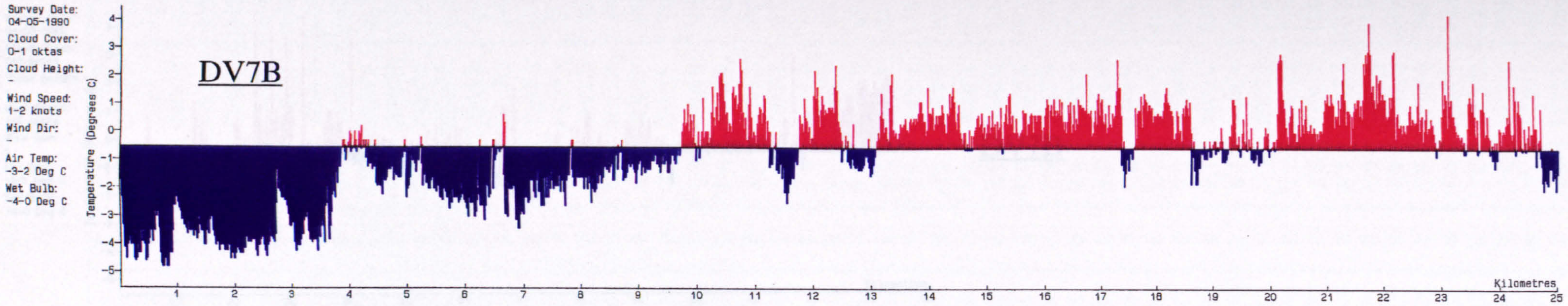


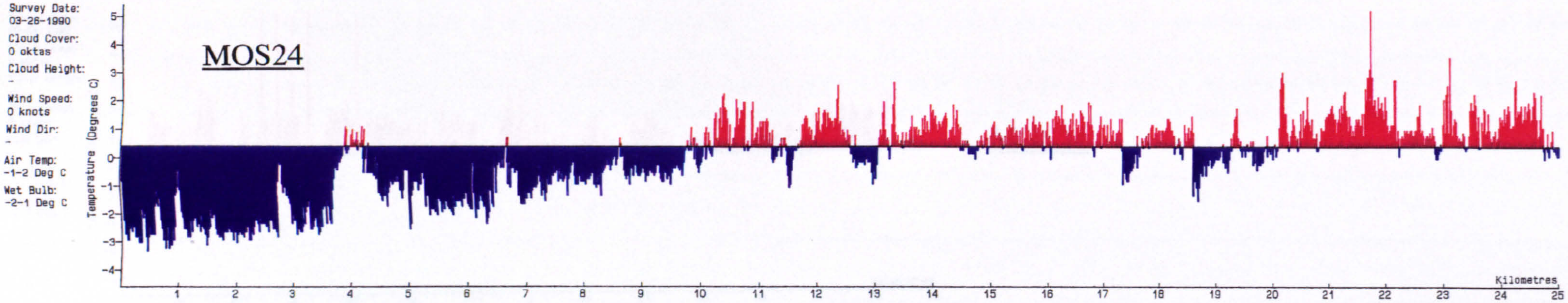
MS11



MS17

Figure 6.24: Extreme Fingerprints of Route 1 Mapped Near Spring Equinox (continued overleaf)





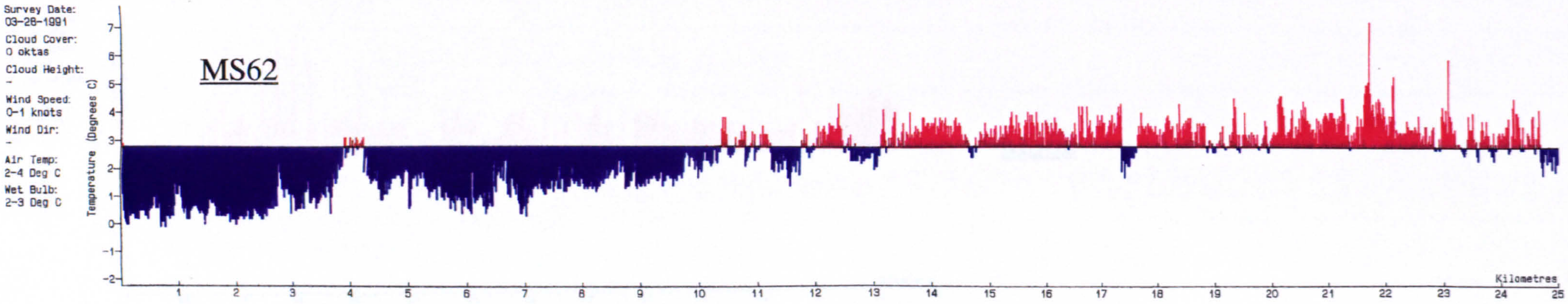
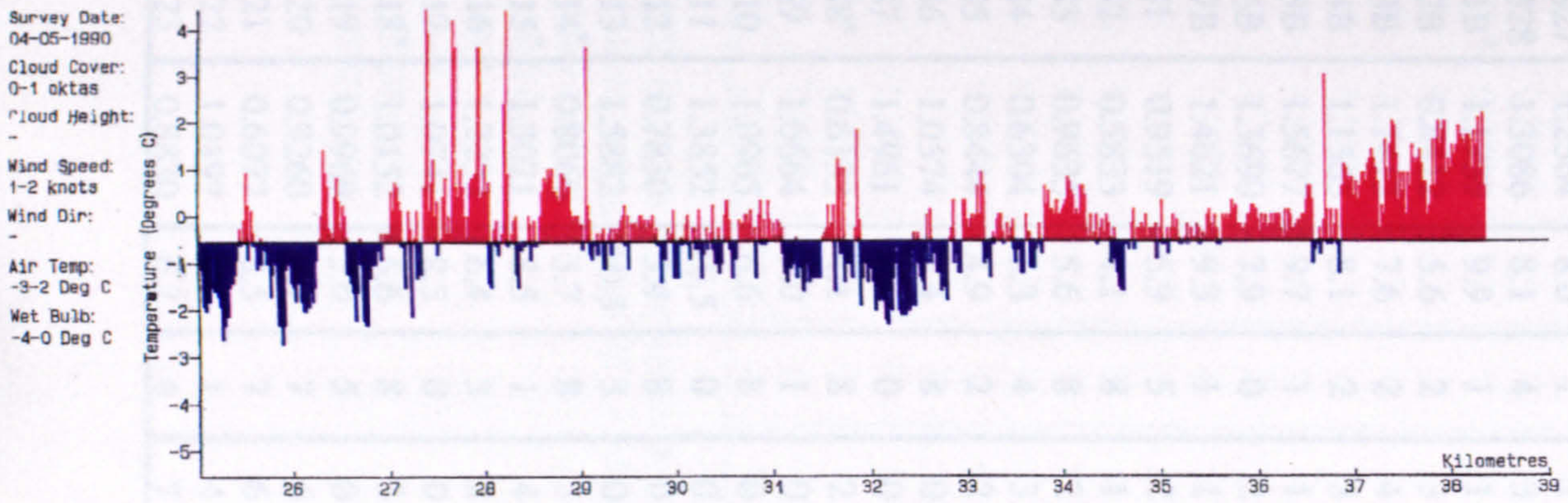
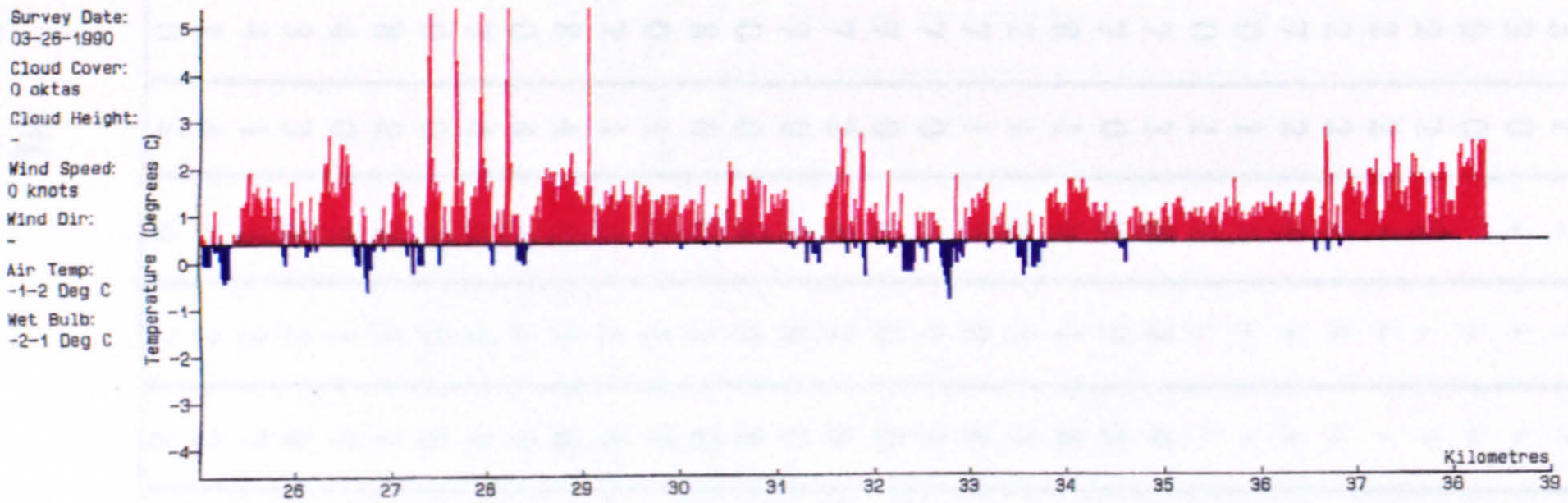


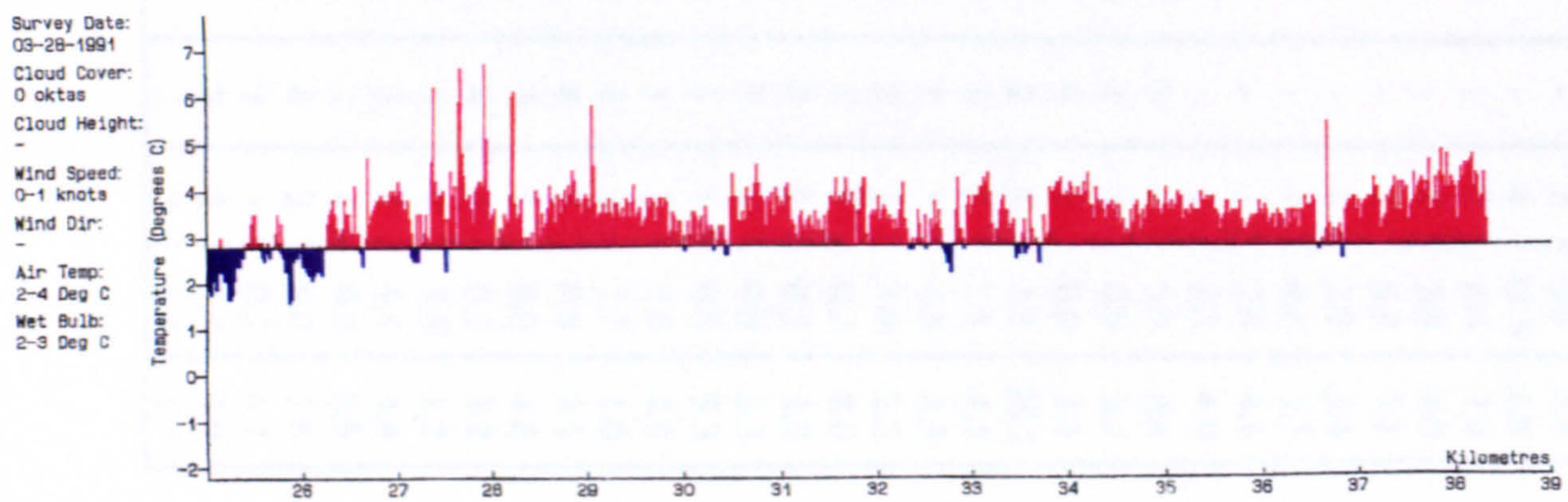
Figure 6.24: Extreme Fingerprints of Route 1 Mapped Near Spring Equinox (continued)



DV7B



MOS24



MS62

Table 6.1: Details of Weather Conditions and Amplitude of Runs Along Route 1 (continued overleaf)

Run	SD	D	Cs	Ws	Ce	We	C0	W0	C3	W3	DM	RD	SUN	Wp
MOS2*	0.6125	5.0	7	6	5	6	-	-	-	-	-	5	0.1	4.1
MOS3*	0.7619	6.3	4	6	1	2	-	-	-	-	-	7	0.0	5.5
MOS4	1.0145	6.3	8	4	8	0	-	-	-	-	-	4	8.1	3.1
MOS5	1.0235	5.6	8	6	8	2	-	-	-	-	-	2	0.0	7.2
MOS6	1.2348	7.1	4	5	2	4	-	-	-	-	-	1	7.3	9.4
MOS7*	0.6701	4.1	8	12	4	9	-	-	-	-	-	6	1.8	9.3
MOS8*	0.9693	6.5	8	7	4	3	-	-	-	-	-	7	2.9	13.3
MOS9	0.8832	6.3	1	4	1	5	-	-	-	-	-	4	0.0	12.4
MOS10*	0.7418	4.7	8	3	1	5	-	-	-	-	-	7	0.0	2.2
MOS11	1.3291	9.2	0	2	0	1	-	-	-	-	-	2	3.1	5.4
MOS12	1.1613	4.9	7	6	5	2	-	-	-	-	-	1	0.6	5.4
MOS13	1.3014	5.5	7	4	6	3	-	-	-	-	-	1	0.2	7.3
MOS14	0.9717	4.7	8	4	8	1	-	-	-	-	-	2	0.1	6.6
MOS15	1.2671	8.3	4	5	2	3	-	-	-	-	-	1	2.2	4.9
MOS16*	1.2074	7.9	4	6	7	7	-	-	-	-	-	5	5.0	5.9
MOS17	0.6691	3.9	8	4	6	4	-	-	-	-	-	4	6.6	8.2
MOS18	0.9692	6.8	8	2	8	1	-	-	-	-	-	1	8.6	3.4
MOS19	1.1997	7.3	3	3	4	2	-	-	-	-	-	1	2.5	5.0
MOS20	0.9453	5.0	7	7	5	3	-	-	-	-	-	1	4.2	6.4
MOS21	0.7520	5.4	7	4	1	2	-	-	-	-	-	4	4.5	5.7
MOS22	1.4261	8.5	0	3	0	1	-	-	-	-	-	1	7.4	8.1
MOS23	0.8702	6.1	2	6	1	2	-	-	-	-	-	4	3.7	6.7
MOS24	1.2782	9.0	0	0	0	0	-	-	-	-	-	1	5.2	5.9
MOS25	0.9300	5.2	8	0	8	0	-	-	-	-	-	1	7.1	3.9
MOS26	1.4235	6.8	3	4	6	2	-	-	-	-	-	1	0.2	5.9
MOS27	1.2564	8.0	1	1	3	1	-	-	-	-	-	2	3.9	5.4
MOS28	1.3086	8.1	4	3	3	0	-	-	-	-	-	4	11.5	6.6
DV1B*	1.1739	9.9	1	1	0	0	-	-	-	-	-	7	8.4	7.9
DV2B	0.8412	5.6	2	3	2	2	-	-	-	-	-	2	5.4	8.0
DV3B	1.1413	7.6	2	4	2	2	-	-	-	-	-	1	6.3	7.7
DV4B	1.1565	8.1	2	3	2	2	-	-	-	-	-	1	3.9	5.4
DV5B	1.5677	9.7	1	1	7	2	-	-	-	-	-	1	4.6	5.5
DV6B	1.3690	7.9	0	2	0	1	-	-	-	-	-	1	2.4	4.1
DV7B	1.4621	9.3	1	1	0	1	-	-	-	-	-	1	2.3	4.0
MS1	0.9519	5.9	5	2	7	3	6	3	4	3	3	1	5.3	6.4
MS2	0.5833	4.1	8	1	7	0	8	0	8	0	4	3	0.0	3.1
MS3	0.9635	5.6	8	2	8	1	8	1	8	1	3	1	0.0	2.1
MS4	0.6304	6.3	4	3	2	1	2	3	3	2	2	5	3.3	10.2
MS5	0.8444	4.9	2	2	7	1	8	0	8	0	3	5	1.8	4.5
MS6	1.0574	5.4	8	0	7	0	5	1	3	0	2	3	4.3	4.5
MS7	1.4961	8.6	0	0	7	0	1	0	0	0	2	3	3.4	2.2
MS8*	0.6133	4.1	8	2	7	2	7	2	6	2	4	5	0.2	8.0
MS9	1.6664	9.0	1	0	7	0	1	0	0	0	2	1	0.3	3.0
MS10	1.0905	6.6	8	0	0	0	8	0	8	0	3	1	0.0	2.3
MS11	1.3852	10.5	0	0	8	0	0	2	0	0	1	1	0.3	5.3
MS12	0.7830	5.4	8	0	0	1	6	1	7	1	3	3	3.6	4.3
MS13	1.5882	10.3	3	0	7	1	0	1	6	0	1	3	3.7	1.0
MS14*	0.8066	3.7	8	3	8	4	8	3	8	3	4	5	0.8	2.1
MS15*	1.3021	8.5	1	4	0	4	3	4	5	1	3	5	0.0	4.6
MS16	1.2233	6.4	3	2	7	4	6	2	7	2	4	4	0.2	8.2
MS17	1.0741	8.3	0	0	0	0	0	0	0	0	1	4	3.8	1.2
MS18*	1.0152	5.6	8	3	8	2	7	3	7	3	3	5	4.4	4.4
MS19	0.9969	5.0	5	0	4	0	5	1	7	1	3	4	0.0	8.9
MS20	0.9260	4.9	7	6	3	3	6	2	8	2	4	2	0.0	7.6
MS21	0.6077	5.5	7	6	4	1	3	2	7	3	2	3	0.3	6.7
MS22	1.0197	8.2	1	4	1	4	0	2	2	3	2	3	0.4	5.9
MS23	0.8830	6.2	4	7	0	4	0	2	8	6	2	5	2.8	5.7

Table 6.1: Details of Weather Conditions and Amplitude of Runs Along Route 1 (continued)

Run	SD	D	Cs	Ws	Ce	We	C0	W0	C3	W3	DM	RD	SUN	Wp
MS24	0.6164	7.2	8	6	3	2	0	1	5	2	2	4	2.2	6.4
MS25*	0.5780	4.1	3	4	5	4	3	5	8	3	4	6	0.8	6.4
MS26	1.2246	9.4	0	0	0	0	0	0	0	0	1	1	0.3	3.9
MS27	1.0482	8.3	0	0	0	0	0	0	0	0	1	3	4.0	2.6
MS28	0.7833	4.4	8	7	8	3	8	4	8	4	4	2	4.8	4.3
MS29	1.3159	11.8	0	1	0	0	0	1	0	0	3	3	5.0	1.2
MS30	1.0169	5.6	8	1	8	1	8	0	8	1	3	1	0.0	1.4
MS31	1.1089	5.0	8	0	8	0	8	1	8	1	3	2	0.0	1.0
MS32	0.8547	4.4	8	0	8	0	8	0	8	0	3	2	0.0	2.7
MS33	0.8434	4.1	8	1	8	0	8	0	8	1	3	2	0.0	1.0
MS34	1.0150	5.0	8	4	7	0	8	0	8	1	3	1	0.0	2.2
MS35	0.6984	4.8	8	2	7	0	8	1	0	0	2	4	0.3	2.6
MS36	1.0372	6.5	0	0	8	0	3	2	0	1	2	3	5.1	4.9
MS37	1.0827	8.4	0	0	0	0	0	0	0	0	2	2	5.2	3.1
MS38	1.2343	7.9	0	1	0	1	7	2	1	1	3	3	0.0	3.6
MS39	0.8184	6.1	8	0	8	1	7	1	7	1	3	2	3.1	4.6
MS40	0.9289	4.8	8	0	8	0	6	0	8	0	3	2	0.7	2.1
MS41	1.3357	9.4	0	0	0	1	0	0	0	0	2	2	1.0	1.3
MS42	0.9644	5.0	8	5	7	2	8	4	7	3	4	2	5.2	4.0
MS43	1.2130	6.3	8	5	8	1	3	3	2	2	3	4	0.0	5.4
MS44*	0.6850	4.2	7	5	2	3	8	3	5	4	5	7	0.0	3.2
MS45	0.8468	4.6	8	3	8	3	8	1	8	2	3	3	8.5	3.4
MS46	1.3793	8.5	0	0	0	0	0	0	0	0	1	3	0.0	3.9
MS47	1.5967	8.4	6	0	7	0	1	1	4	1	2	1	3.9	4.4
MS48	1.0092	7.7	0	0	8	0	0	0	0	0	1	1	8.2	10.7
MS49	0.8383	3.9	7	9	5	2	8	4	5	4	5	5	0.0	6.3
MS50*	0.6584	3.1	8	1	8	0	7	0	8	0	3	6	0.0	3.7
MS51	0.5405	2.7	8	4	8	2	8	1	8	2	3	5	0.0	3.7
MS52	0.7428	5.0	6	3	7	0	4	0	1	0	2	1	3.5	5.4
MS53	0.5319	2.5	8	0	8	0	8	0	8	0	3	2	0.2	4.4
MS54	0.8080	4.4	8	3	8	0	8	0	8	0	3	2	0.0	2.8
MS55	1.2198	6.3	8	0	8	1	7	0	1	0	3	1	2.3	2.7
MS56	0.9777	6.5	6	5	7	2	8	2	8	3	4	2	0.2	4.6
MS57	1.3956	6.8	1	3	1	2	5	2	3	1	3	2	5.7	8.9
MS58	1.2865	6.4	8	1	8	1	5	1	8	1	3	2	7.4	5.9
MS59	1.1096	6.2	8	0	8	0	7	1	8	1	3	1	6.0	2.7
MS60	0.6910	5.3	8	2	8	1	0	1	7	0	2	1	0.0	3.7
MS61	0.7401	5.1	8	6	8	2	8	3	8	2	3	1	0.3	5.7
MS62	1.1133	7.3	0	1	0	0	0	0	0	1	1	1	3.2	5.4
MS63	1.1333	8.3	0	2	0	1	8	1	1	1	3	4	0.0	9.1
MS64	1.2386	6.9	8	4	7	2	0	1	4	3	2	2	10.0	6.7
MS65	1.1339	6.9	6	4	7	1	0	0	7	1	2	1	3.2	7.6
MS66	1.1531	5.7	4	0	7	2	1	4	0	3	5	1	6.5	7.9

NOTES: See table 5.1 for details of dates and classification of runs.

D = difference (maximum RST - minimum RST)
C = cloud (octas)
W = wind (m/s)
s = start of run
e = end of run
0 = at 0000hrs
3 = at 0300hrs

DM = weather conditions dusk-midnight
RD = road conditions (see text)
SUN = hours sunshine previous day
Wp = wind previous day (m/s, average of period 1000-1359hrs, Geog. Dept)

*excluded from some analysis

Table 6.2: Summary of Regressions of SD

SD Regressed Against:	Data Set	Regression Equation	R^2(%)	Correlation Coefficient	Significance Level (%)
cloud start	100	SD = 1.26 - 0.047Cs	31.4	-0.5604	1
wind start	"	SD = 1.13 - 0.038Ws	11.5	-0.3391	1
cloud end	"	SD = 1.14 - 0.023Ce	7.6	-0.2757	1
wind end	"	SD = 1.09 - 0.037WE	5.2	-0.2280	5
sun previous day	"	SD = 0.96 + 0.025SUN	6.8	+0.2608	1
road conditions	"	SD = 1.21 - 0.065RD	18.2	-0.4266	1
wind previous day	"	SD = 1.06 - 0.007Wp	0.4	-0.0632	-
cloud start	86 (snow etc removed)	SD = 1.26 - 0.043Cs	30.4	-0.5514	1
cloud start	66 (runs 1990/91)	SD = 1.22 - 0.043Cs	28.2	-0.5310	1
wind start	"	SD = 1.10 - 0.047Ws	15.3	-0.3912	1
cloud end	"	SD = 1.13 - 0.025Ce	8.8	-0.2966	2
wind end	"	SD = 1.05 - 0.041We	3.8	-0.1949	-
cloud 0000hrs	"	SD = 1.17 - 0.037C0	20.5	-0.4528	1
wind 0000hrs	"	SD = 1.04 - 0.033W0	2.6	-0.1612	-
cloud 0300hrs	"	SD = 1.19 - 0.040C3	24.1	-0.4909	1
wind 0300hrs	"	SD = 1.07 - 0.058W3	8.3	-0.2881	1
DM	"	SD = 1.27 - 0.098DM	12.6	-0.3550	1

Table 6.3: Summary of Regressions of Difference (D)

SD Regressed Against:	Data Set	Regression Equation	R^2(%)	Correlation Coefficient	Significance Level (%)
Cloud start	100 runs route 1	D = 8.52 - 0.437Cs	58.3	-0.7635	1
Wind start	"	D = 7.08 - 0.247Ws	10.6	-0.3256	1
Cloud end	"	D = 7.92 - 0.328Ce	32.2	-0.5675	1
Wind end	"	D = 6.78 - 0.238We	4.7	-0.2168	5
Sun previous day	"	D = 5.90 + 0.185SUN	8.0	+0.2828	1
Road condition	"	D = 7.10 - 0.253RD	5.8	-0.2408	2
Wind previous day	"	D = 6.45 - 0.09Wp	0.0	-0.0000	-
Cloud start	86 (removed snow etc)	D = 8.49 - 0.417Cs	58.2	-0.7629	1
Cloud start	66 runs 1990/91	D = 8.42 - 0.433Cs	55.6	-0.7457	1
Wind start	"	D = 6.81 - 0.280Ws	10.7	-0.3271	1
Cloud end	"	D = 8.04 - 0.354Ce	36.2	-0.6017	1
Wind end	"	D = 6.56 - 0.294We	3.9	-0.1975	-
Cloud 0000hrs	"	D = 8.11 - 0.417C0	51.5	-0.7176	1
Wind 0000hrs	"	D = 6.55 - 0.257W0	3.1	-0.1761	-
Cloud 0300hrs	"	D = 8.10 -0.393C3	45.0	-0.6708	1
Wind 0300hrs	"	D = 6.78 - 0.441W3	9.5	-0.3082	2
DM	"	D = 8.72 - 0.241K4	35.7	-0.5975	1

Table 6.4: Summary of Regressions With Extreme Runs

Regressed Against:	Data Set	Regression Equation	R^2(%)	Correlation Coefficient (R)	Significance Level (%)
SD					
cloud start	13 extreme 1990/91	SD = 1.23 + 0.439Cs	40.1	+0.6332	5
wind start	"	SD = 1.27 - 0.052Ws	1.4	-0.1183	-
cloud end	"	SD = 1.26 - 0.002Ce	0.0	-0.0000	-
wind end	"	SD = 1.26 + 0.028We	0.3	+0.0548	-
sun previous day	"	SD = 1.39 - 0.051SUN	32.4	-0.5692	5
road conditions	"	SD = 1.40 - 0.606RD	10.6	-0.3256	-
wind previous day	"	SD = 1.32 - 0.017Wp	1.7	-0.1304	-
cloud 0000hrs	"	SD = 1.27 - 0.005C0	0.2	-0.0447	-
wind 0000hrs	"	SD = 1.27 - 0.021W0	1.0	-0.1000	-
cloud 0300hrs	"	SD = 1.26 - 0.029C3	0.2	-0.0447	-
wind 0300hrs	"	SD = 1.30 - 0.173W3	15.5	-0.3937	-
DM	"	SD = 1.17 + 0.055DM	4.5	+0.2121	-
D					
cloud start	13 extreme 1990/91	D = 8.74 + 0.260Cs	0.3	+0.0548	-
wind start	"	D = 8.69 + 0.310Ws	1.0	+0.1000	-
cloud end	"	D = 8.99 - 0.201Ce	17.7	-0.4207	-
wind end	"	D = 8.78 - 0.130We	0.1	-0.0316	-
sun previous day	"	D = 9.01 - 0.103SUN	2.7	-0.1643	-
road conditions	"	D = 9.31 - 0.239RD	3.3	-0.1817	-
wind previous day	"	D = 9.91 - 0.359Wp	15.5	-0.3937	-
cloud 0000hrs	"	D = 9.00 - 0.260C0	15.2	-0.3899	-
wind 0000hrs	"	D = 8.75 + 0.029W0	0.0	+0.0000	-
cloud 0300hrs	"	D = 8.83 - 0.013C3	3.7	-0.1924	-
wind 0300hrs	"	D = 9.22 - 1.990W3	41.8	-0.6465	2
DM	"	D = 8.15 + 0.361DM	4.1	+0.2025	-

Table 6.5: Summary of Regressions with Damped Runs

Regressed Against:	Data Set	Regression Equation	R^2(%)	Regression Coefficient (R)	Significance Level (%)
SD					
cloud start	11 damped runs	SD = 1.34 - 0.057Cs	1.6	-0.1265	-
wind start	"	SD = 1.01 - 0.021Ws	16.4	-0.4050	-
cloud end	"	SD = 0.07 + 0.029 Ce	12.8	+0.3578	-
wind end	"	SD = 1.03 - 0.046We	62.0	-0.7874	1
sun previous day	"	SD = 0.90 - 0.002SUN	0.2	-0.0447	-
road condition	"	SD = 0.96 - 0.018RD	6.4	-0.2530	-
wind previous day	"	SD = 0.93 - 0.006Wp	2.0	-0.1414	-
D					
cloud start	11 damped runs	D = 5.14 - 0.020Cs	0.0	-0.0000	-
wind start	"	D = 5.17 - 0.033Ws	0.9	-0.0949	-
cloud end	"	D = 5.09 - 0.016Ce	0.1	-0.0316	-
wind end	"	D = 5.67 - 0.228We	31.8	-0.5639	10
sun previous day	"	D = 4.71 + 0.076SUN	4.7	+0.2168	-
road condition	"	D = 4.74 + 0.066RD	1.9	+0.1379	-
wind previous day	"	D = 4.53 + 0.073Wp	6.2	+0.2490	-

Table 6.6: RST and Cooling Rates at Icelert Sensors Night of 13/14.1.92

Sensor	Time (hrs)								Cooling Rates (°C/hr)			
	2100		0000		0300		0600		Time (hrs)			
	RST	Rel.	RST	Rel.	RST	Rel.	RST	Rel.	2100-0000	0000-0300	0300-0600	2100-0600
Moscar Top	+2.4	0.0	+1.8	0.0	+1.2	0.0	+0.6	0.0	0.20	0.20	0.20	0.20
Elliott Lane	+3.8	+1.4	+2.8	+1.0	+1.6	+0.4	+1.0	+0.4	0.33	0.40	0.20	0.31
Tinsley	+5.0	+2.6	+3.8	+2.0	+2.4	+1.2	+1.8	+1.2	0.40	0.47	0.20	0.36
PWR	+4.3	+1.9	+2.8	+1.0	+1.7	+0.5	+1.0	+0.4	0.50	0.37	0.23	0.37
Birley Moor	+3.0	+0.6	+1.8	0.0	+0.5	-0.7	0.0	-0.6	0.40	0.43	0.17	0.33
Ringinglow	+2.4	0.0	+1.8	0.0	+1.2	0.0	+0.6	0.0	0.20	0.20	0.20	0.20
Brad/Pros	+2.6	+0.2	+1.6	-0.2	+0.6	-0.6	-0.2	-0.8	0.33	0.33	0.27	0.31
Hillfoot	+3.8	+1.4	+2.7	+0.9	+1.9	+0.7	+1.0	+0.4	0.37	0.27	0.30	0.31

NOTES: PWR = Prince of Wales Road
RST = road surface temperature (°C)
rel. = road surface temperature relative to Moscar Top (°C), + = warmer than Moscar Top

Table 6.7: RST and Cooling Rates at Icelert Sensors Night of 16/17.1.92

Sensor	Time (hrs)								Cooling Rates (°C/hr)			
	2100		0000		0300		0600		Time (hrs)			
	RST	Rel.	RST	Rel.	RST	Rel.	RST	Rel.	2100-0000	0000-0300	0300-0600	2100-0600
Moscar Top	+1.2	0.0	+0.6	0.0	+0.2	0.0	-0.2	0.0	0.20	0.13	0.13	0.16
Elliott Lane	+3.2	+2.0	+2.6	+2.0	+2.2	+2.0	+1.4	+1.6	0.20	0.13	0.27	0.20
Tinsley	+4.2	+3.0	+2.8	+2.2	+2.4	+2.2	+1.4	+1.6	0.47	0.13	0.33	0.31
PWR	+3.4	+2.2	+2.2	+1.4	+1.7	+1.5	+0.8	+1.0	0.40	0.17	0.30	0.27
Birley Moor	+2.2	+1.0	+1.5	+0.9	+1.3	+1.1	+0.5	+0.7	0.23	0.07	0.27	0.19
Ringinglow	+1.0	-0.2	+0.4	-0.2	+0.6	+0.4	-0.2	0.0	0.20	(0.07)	0.27	0.13
Brad/Pros	+0.4	-0.8	+0.2	-0.4	-0.4	-0.6	-0.6	-0.4	0.07	0.20	0.07	0.11
Hillfoot	+3.6	+2.4	+2.4	+1.8	+1.8	+1.6	+1.4	+1.6	0.40	0.20	0.13	0.24

NOTES: PWR = Prince of Wales Road
RST = road surface temperature (°C)
rel. = road surface temperature relative to Moscar Top (°C), + = warmer than Moscar Top

Table 6.8: RST and Cooling Rates at Icelert Sensors Night of 21/22.1.92

Sensor	Time (hrs)								Cooling Rates (°C/hr)			
	2100		0000		0300		0600		Time (hrs)			
	RST	Rel.	RST	Rel.	RST	Rel.	RST	Rel.	2100-0000	0000-0300	0300-0600	2100-0600
Moscar Top	-2.0	0.0	-2.6	0.0	-2.8	0.0	-3.2	0.0	0.20	0.07	0.13	0.13
Elliott Lane	-0.6	+1.4	-1.5	+1.1	-2.0	+0.8	-2.4	+0.8	0.30	0.17	0.13	0.20
Tinsley	+1.4	+3.4	+0.2	+2.8	-0.8	+2.0	-1.4	+1.8	0.40	0.33	0.20	0.31
PWR	-0.3	+1.7	-1.6	+1.0	-2.3	+0.5	-2.8	+0.4	0.43	0.23	0.17	0.28
Birley Moor	-1.5	+0.5	-2.0	+0.6	-2.5	+0.3	-2.8	+0.4	0.17	0.17	0.10	0.14
Ringinglow	-1.9	+0.1	-2.1	+0.5	-2.5	+0.3	-2.8	+0.4	0.07	0.13	0.10	0.10
Brad/Pros	-1.8	+0.2	-2.7	-0.1	-3.2	-0.4	-3.6	-0.4	0.30	0.17	0.13	0.20
Hillfoot	0.0	+2.0	-0.9	+1.7	-1.7	+1.1	-2.3	+0.9	0.30	0.27	0.20	0.26

NOTES: PWR = Prince of Wales Road
RST = road surface temperature (°C)
rel. = road surface temperature relative to Moscar Top (°C), + = warmer than Moscar Top

Table 6.9: Details of Runs DV1-7a and b

Run	Date	Cloud Start (octas)	Wind Start (m/s)	Cloud End (octas)	Wind End (m/s)	SD	Notes
DV1A	15.2.90	1	2	0	0	1.2815	Snow on roads (Moscar Top)
DV1B	16.2.90	1	1	0	0	1.1739	"
DV2A	2.3.90	7	4	5	1	1.0161	
DV2B	3.3.90	2	3	2	2	0.8412	
DV3A	11.3.90	3	2	2	3	1.1148	
DV3B	12.3.90	2	4	2	2	1.1413	
DV4A	17.3.90	0	2	0	0	1.4426	
DV4B	18.3.90	2	3	2	2	1.1565	Cloud thin and high
DV5A	19.3.90	2	2	0	1	1.5796	
DV5B	20.3.90	1	1	7	2	1.5677	Thin cloud after start of run
DV6A	28.3.90	0	0	0	1	1.5799	
DV6B	29.3.90	0	2	8	0	1.3690	Thin cloud thickening during run
DV7A	4.4.90	0	1	0	1	1.5738	
DV7B	5.4.90	1	2	0	1	1.4621	

Table 6.10: Details of Runs DB1-4a and b

Run	Date	Cloud Start (octas)	Wind Start (m/s)	Cloud End (octas)	Wind End (m/s)	Air Temp. (°C)		Cold Air Pool (°C)[3]	Road Temp. (°C)[2]	Notes
						1	2			
DB1A	16.1.92	0	3	0	0	+0.9	-1.7	-2.6	-3.4	
DB1B	-	-	-	-	-	-	-	-	-	Extensive fog
DB2A	21.1.92	0	0	0	0	-4.7	-7.8	-3.1	-7.3	
DB2B	22.1.92	0	0	0	0	-4.8	-8.0	-3.2	-7.3	
DB3A	26.1.92	0	1	0	1	+0.1	-4.7	-4.8	-5.3	
DB3B	27.1.92	0	2	0	0	0.0	-6.5	-6.5	-6.6	
DB4A	27.1.92	0	0	0	0	-2.8	-4.9	-2.1	-5.7	
DB4B	28.1.92	0	2	0	0	-1.2	-4.9	-3.7	-4.7	Fog in Hope Valley

NOTES: 1 = start of run, 410m.asl
2 = near Hope station 170m.asl
3 = temperature at 1 - temperature at 2

Table 6.11: Cold Air Pool Intensity Route 2

Run	Date	Start Time (hrs)	Cooling Period (mins.)	Wind Direction		Wind Speed (m/s)[3]		Cold Air Pool (°C)
				HB[1]	GD[2]	HB	GD	
ECC4	4.12.90	0145	595	NW-NNW	WNW	5.4	5.0	-0.8
ECC7	15.12.90	0055	550	NW-NNW	SSE-S/Calm	1.6	0.5	-1.1
ECC14	23.1.91	0148	560	WSW	SSW-SW	3.7	1.4	-1.2
ECC19	14.2.91	0312	600	WNW-NW	W-WNW	3.1	1.7	-1.1
ECC22	19.2.91	0310	590	WSW	SW-WSW	3.6	2.1	-1.9

Cold air pool at 3.3km along run (65m.asl), relative to 2.6km (100m.asl).

Table 6.12: Cold Air Pool Intensity Route 6

Run	Date	Start Time (hrs)	Cooling Period (mins.)	Wind Direction		Wind Speed (m/s)[3]		Cold Air Pool (°C)
				HB[1]	GD[2]	HB	GD	
RNG3	29.11.90	0306	670	N	NNW-NNE	2.3	1.0	-1.3
RNG4	6.12.90	0028	520	W-WNW	W-WNW	3.6	2.2	-3.2
RNG6	15.12.90	0130	585	NW-NNW	SSE-S/Calm	1.6	0.5	-2.6
RNG11	13.1.91	0322	670	-	NW-NNW	3.0	2.6	-2.1

Cold air pool at 28.55km along run (35m.asl), relative to 26.0km (120m.asl).

Table 6.13: Cold Air Pool Intensity Route 7

Run	Date	Start Time (hrs)	Cooling Period (mins.)	Wind Direction		Wind Speed (m/s)[3]		Cold Air Pool (°C)
				HB[1]	GD[2]	HB	GD	
AB11	12.1.91	0218	605	-	SSW-SW	5.5	2.6	-0.6
AB12	13.1.91	0220	610	-	NW-NNW	3.1	3.0	-1.5
AB13	14.1.91	0120	545	-	S/Calm	2.1	0.3	-0.9
AB14	16.1.91	0302	645	WSW-W	S-SSW	4.5	1.0	-1.2
AB18	27.2.91	0300	565	-	SW-SE/Var.	-	1.2	-2.0

Cold air pool at 6.0km along run (110m.asl), relative to 0.1km (265m.asl)

NOTES: 1) High Bradfield
2) Geography Department
3) Wind speed average of 2 hours before run, hour when run made and hour after run.

Table 6.14: Cold Air Pool Intensity Route 1

Run	Date	Cooling Period (mins.)	Wind Direction		Wind Speed(m/s)[3]		Cold Air Pool (°C)
			HB[1]	GD[2]	HB	GD	
DV1B*	16.2.90	675	WNW-NW	W-WNW	6.7	1.9	0.0
MOS11	2.3.90	645	-	NW	10.6	5.7	+0.9
MOS24	26.3.90	540	NNW-N	WNW-NW	4.9	3.1	-0.3
DV7B*	5.4.90	525	-	SSE-SW	4.9	1.0	-0.2
MS7	22.11.90	750	E	NW-NNW	3.6	1.4	-0.4
MS9	29.11.90	755	N	NNW	2.7	1.0	+0.5
MS11*	9.12.90	760	NNW	WNW	6.7	4.3	-0.2
MS17*	15.12.90	765	NNW-N	N	3.1	0.8	-0.2
MS26*	13.1.91	740	-	WNW-NNW	3.0	1.4	-0.1
MS27*	16.1.91	735	WSW-W	SSW	4.9	1.0	-0.1
MS29	23.1.91	720	WSW	SSW-W	3.8	1.4	-1.0
MS36	12.2.91	680	WNW-NW	W-WNW	6.4	3.5	-1.1
MS37	14.2.91	680	W-NW	W-WNW	3.4	2.8	-1.9
MS38	16.2.91	675	NNW-N	NNW	5.8	4.4	+0.6
MS41	19.2.91	670	WSW	SSW-WSW	4.1	2.3	-1.1
MS46*	27.2.91	655	-	SE/Calm/Var	-	0.8	-0.1
MS62*	28.3.91	600	-	NNW	-	3.4	+0.5

NOTES: Cold air pool at 17.5km along run (65m.asl), relative to 9.6km (190m.asl).

1) High Bradfield
2) Geography Department
3) Wind speed average of period 0200-0600hrs.

* clear/calm all night

Table 6.15: Location of Lowest RSTs Recorded on Extreme Runs of Route 1

Run	Location (km along run)		
	Lowest RST	Second Lowest RST	Third Lowest RST
MOS11	0.1	0.8	2.75
MOS24	0.4	0.8	0.5/6.0
DV1B	0.1	0.8	0.5/6.0
DV7B	0.8	0.3	2.0
MS7	3.65	3.4	5.0
MS9	0.1	3.7	0.75/2.2/3.2
MS11	0.1	0.3	1.2
MS17	0.8	2.6	2.2
MS26	2.7	5.0	2.0/3.1
MS27	0.8/6.9	6.3	3.7
MS29	0.8	0.1	3.7
MS36	0.1/0.4/0.8/17.5	2.8	2.0
MS37	0.2/3.2	2.2	0.85
MS38	0.1/1.2	2.2/3.0	1.8
MS41	2.6/3.2	3.7	0.8/7.0
MS46	2.7	3.6	6.3
MS62	0.8	0.1	1.4/2.0

Table 6.16: RST Pattern Along First 8km of Route 1 (Extreme runs)

Pattern of RST	Frequency	Runs with wind speed (m/s) and direction (HB spd, HB dir; GD spd, GD dir)
High and intermediate altitudes coldest, low altitudes least cold	5	MOS11 (-,10.6;NW,5.7) MOS24 (NNW-N,4.9;WNW-NW,3.1) DV7B (-,4.9;SSE-SW,1.0) MS9 (N,2.7;NNW,1.0) MS17 (NNW-N,3.1;N,0.8)
High, intermediate and low altitudes at a similar temperature	5	MS27 (WSW-W,4.9;SSW,1.0) MS29 (WSW,3.8;SSW-W,1.4) MS36 (WNW-NW,6.4;W-WNW,3.5) MS38 (NNW-N,5.8;NNW,4.4) MS62 (-,-;NNW,3.4)
Intermediate and low altitudes at similar temperatures, high altitudes less cold	2	MS26 (-,3.0;WNW-NNW,1.4) MS46 (-,-;SE/Calm/Var,0.8)
Intermediate altitudes coldest, then low altitudes, high altitudes least cold	2	MS7 (E,3.6;NW-NNW,1.4) MS41 (WSW,4.1;SSW-WSW,2.3)
High and low altitudes coldest, intermediate altitudes least cold	1	DV1B (WNW-NW,6.7;W-WNW,1.9)
Intermediate altitudes coldest, then high altitudes, low altitudes least cold	1	MS37 (W-NW,3.4;W-WNW,2.8)
High altitudes coldest, then intermediate, low altitudes least cold	1	MS11 (NNW,6.7;WNW,4.3)

Photo 6.1: Location of Tinsley Icelert Sensor

Photo 6.2: Location of Prince of Wales Road Icelert Sensor

Photo 6.3: Location of Hillfoot Icelert Sensor

Photo 6.4: Location of Moscar Top Icelert Sensor

Photo 6.5: Location of Ringinglow Icelert Sensor

Photo 6.6: Location of Elliott Lane Icelert Sensor

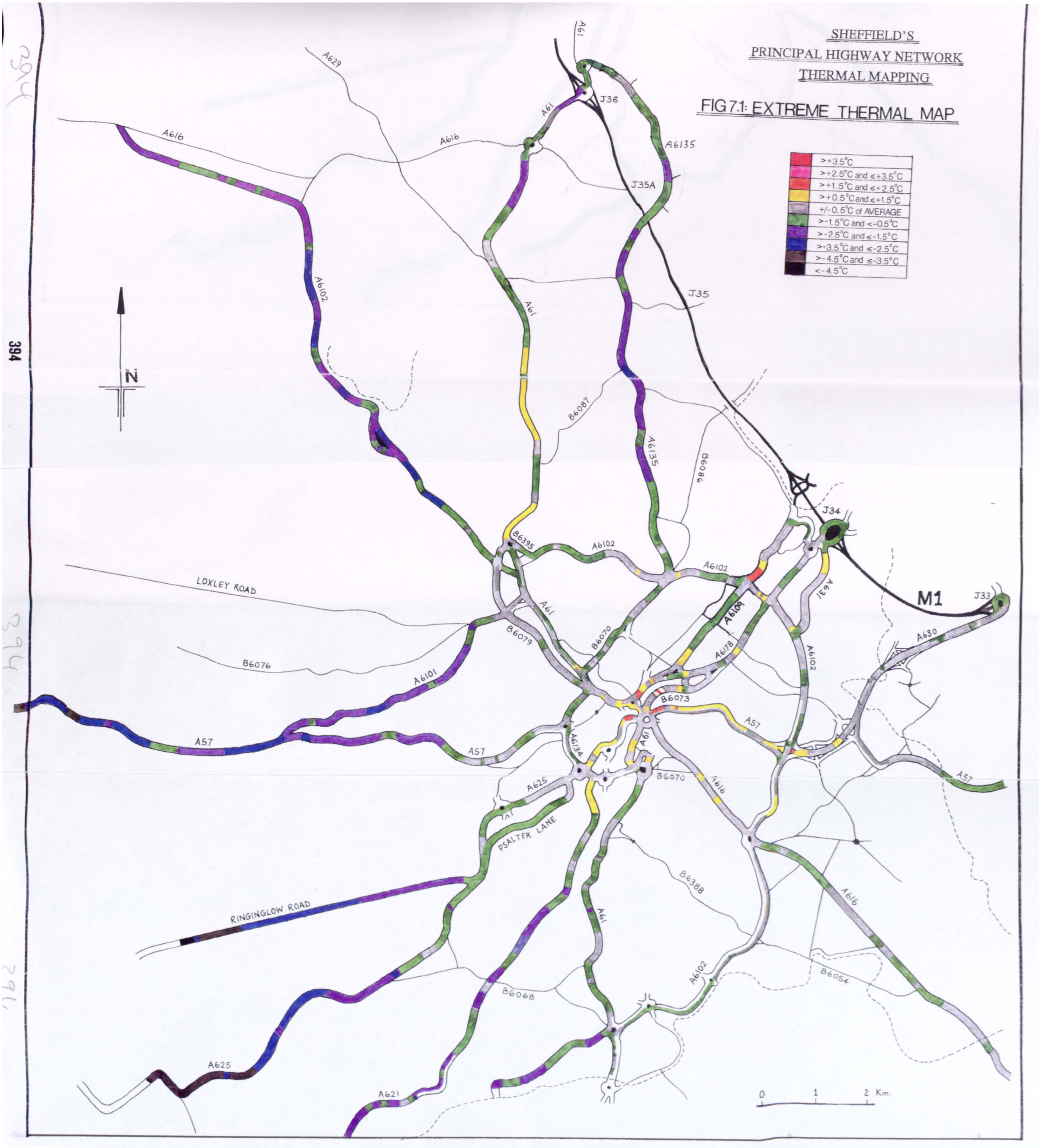
Photo 6.7: Location of Birley Moor Icelert Sensor

Photo 6.8: Location of Bradway/Prospect Road Icelert Sensor

CHAPTER 7

SHEFFIELD'S PRINCIPAL HIGHWAY NETWORK THERMAL MAPPING

FIG 7.1: EXTREME THERMAL MAP



SHEFFIELD'S
PRINCIPAL HIGHWAY NETWORK
THERMAL MAPPING

FIG7.2:DAMPED THERMAL MAP

Figure 7.3: Fingerprints Of Sheffield Combined Run (continued overleaf)

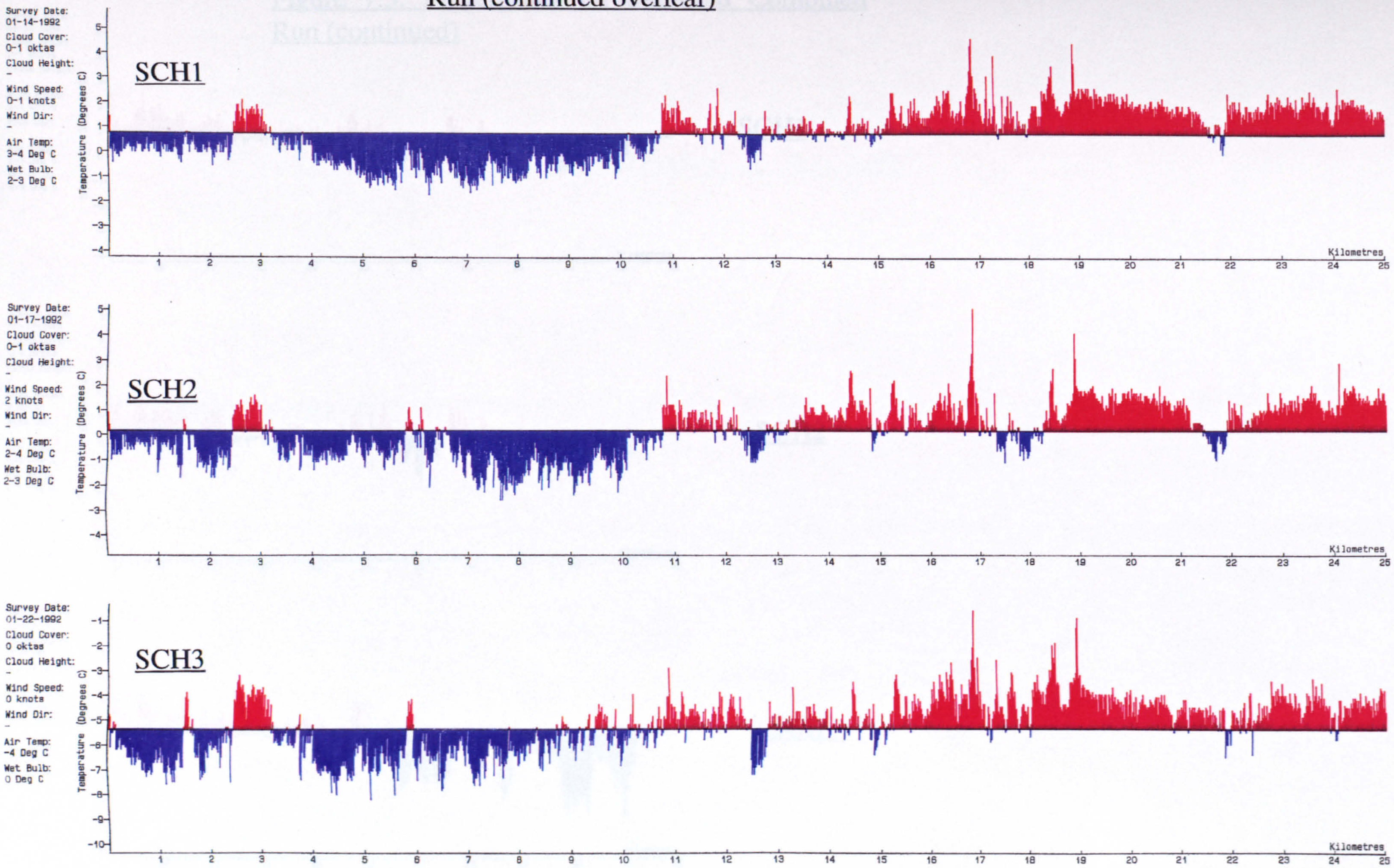
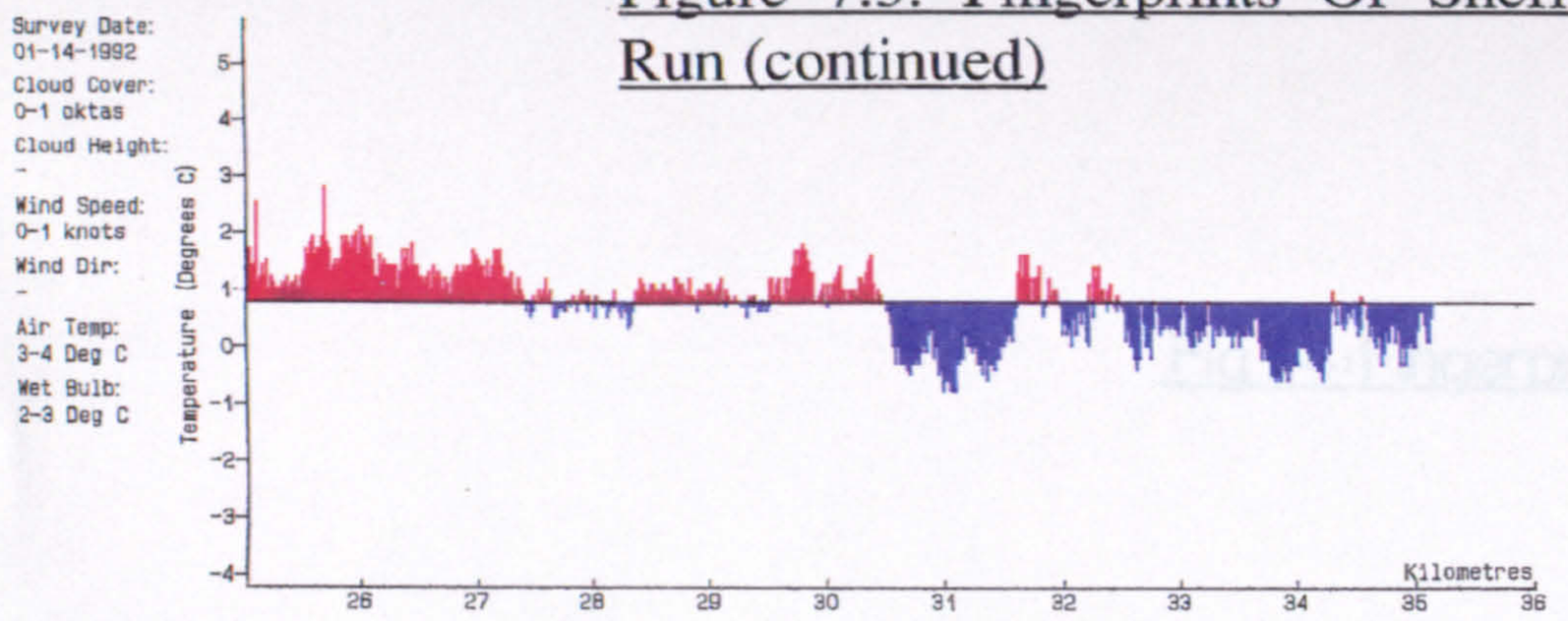
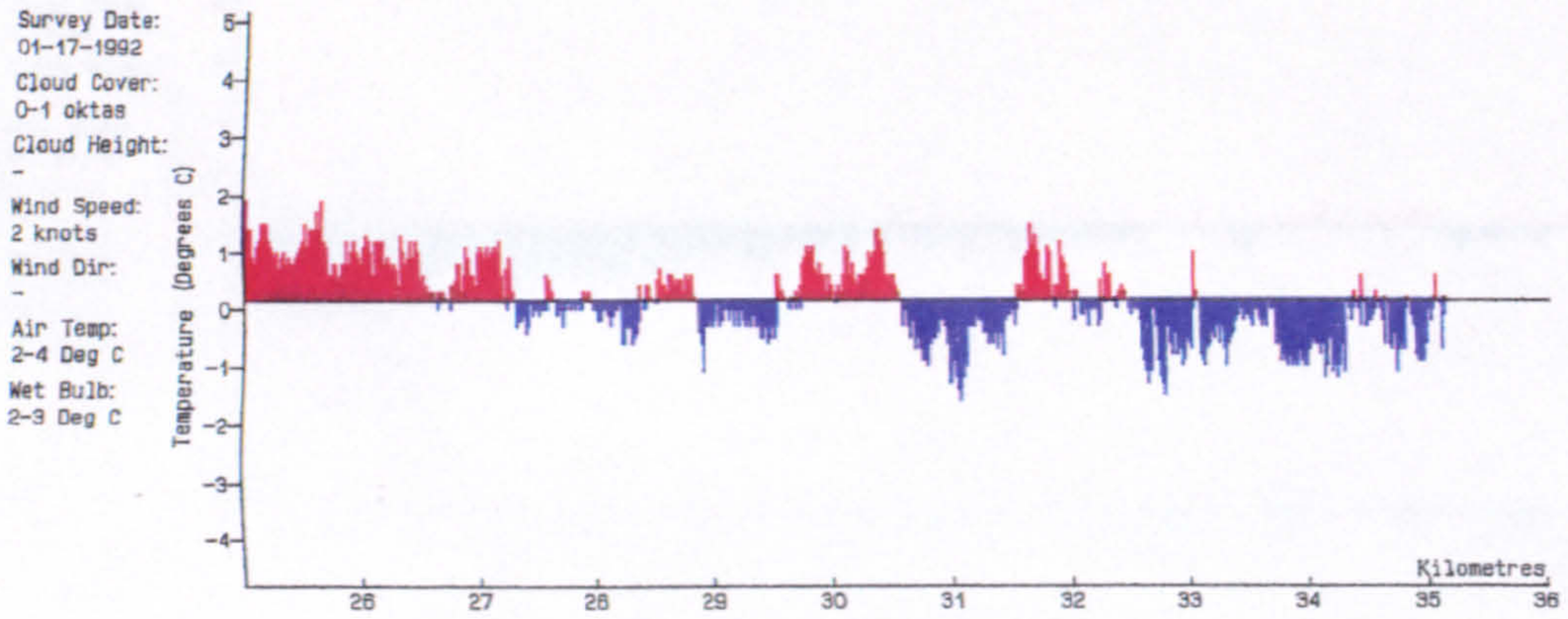


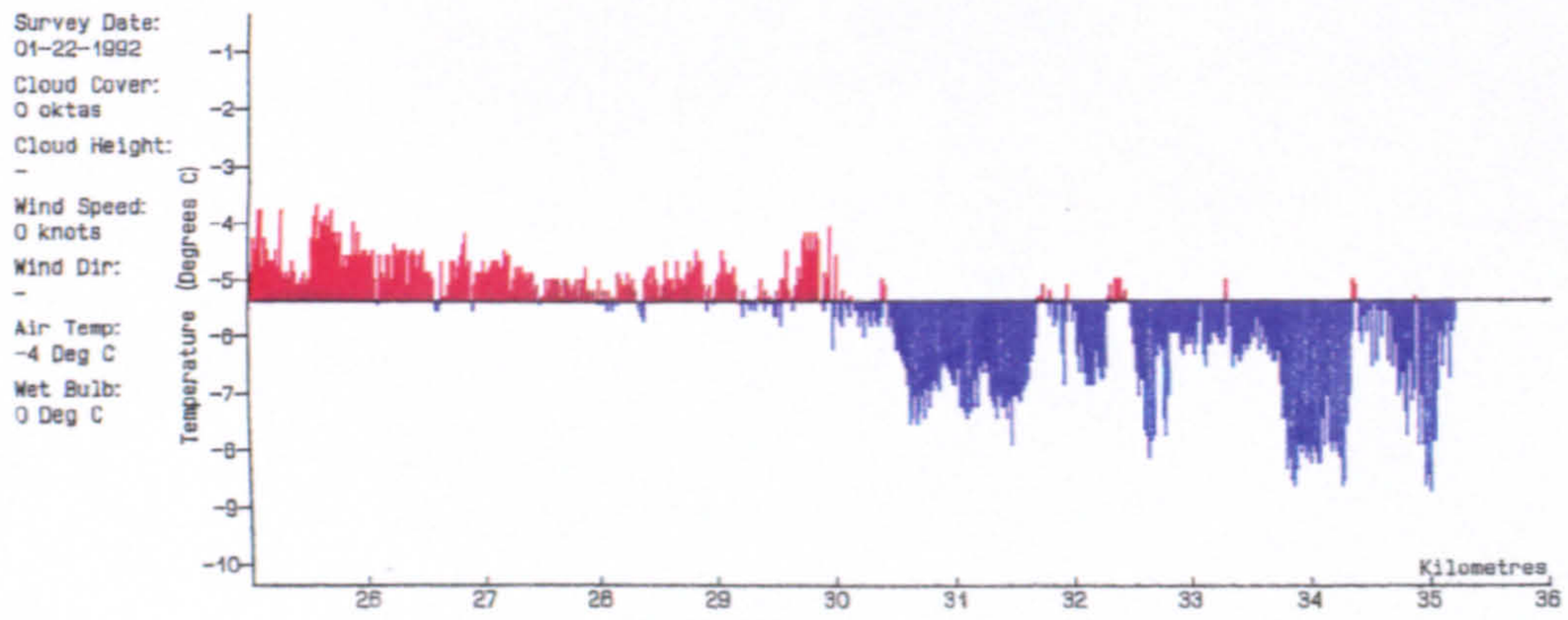
Figure 7.3: Fingerprints Of Sheffield Combined Run (continued)



SCH1



SCH2



SCH3

Fig 7.4: Fingerprint of Run AB5

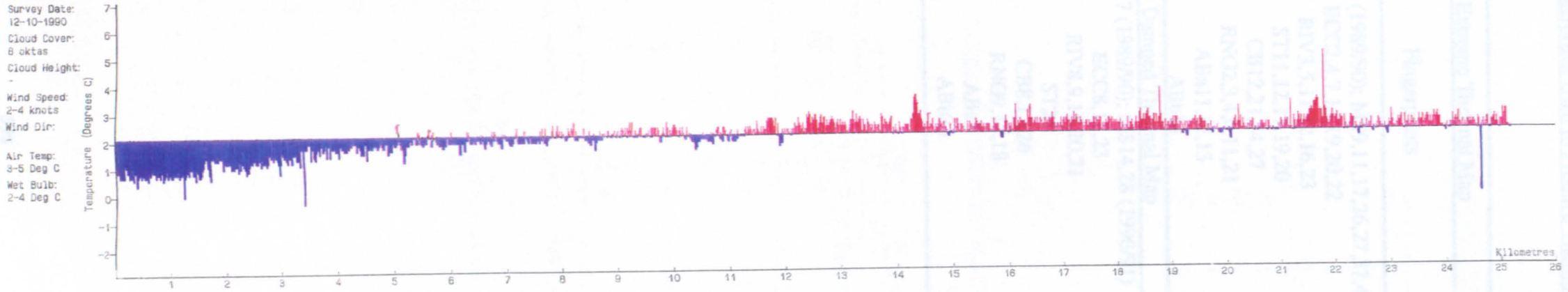


Table 7.1: Fingerprints Used to Produce Thermal Maps

	Extreme Thermal Map	
Route	Fingerprints	Average Fingerprint
1	MOS11,22,24 DV1,5,7B (1989/90); MS9,11,17,26,27,37,41,62 (1990/91)	MS.AV.E
2	ECC2,4,7,14,19,20,22	EC.AV.E
3	RIV3,5,11,12,16,23	RIV.AV.E
4	ST11,12,17,19,20	ST.AV.E
5	CB12,21,24,27	CB.AV.E
6	RNG2,3,4,6,11,21	RNG.AV.E
7a	ABa11,12,13	ABA.AV.E
7b	ABb14	-
	Damped Thermal Map	
1	MOS7,17 (1989/90); MS14,28 (1990/91)	MS.AV.D
2	ECC8,13,23	EC.AV.D
3	RIV8,9,18,20,21	RIV.AV.D
4	ST24	-
5	CB8,13,26	CB.AV.D
6	RNG9,12,18	RNG.AV.D
7a	ABa5	-
7b	ABb23	-

Table 7.2: Comparison Between Extreme Thermal Map and SCH Runs

Section of SCH Fingerprint (km)	Temperature compared to extreme thermal map		
	SCH1	SCH2	SCH3
0.0-2.4	+	+	+
2.4-3.0	+	+	++
5.0-6.0	+	+	+/0
10.0-12.0	0	0	0
12.5-12.8	0	0/-	0/-
20.0-21.0	0	0	0
23.0-24.0	0	0/0	0
27.0-28.5	**0**	**0**	0
30.0-35.0	0	0	0/-

NOTES: + = warmer
- = colder
0 = similar
0 = very similar

Table 7.3: Comparison Between Icelert Temperatures and Extreme Thermal Map

Sensor	Temperature Range (°C)[1]	Night of (January 1992)											
		13/14				16/17				21/22			
		Time of night (....00hrs)											
		21	00	03	06	21	00	03	06	21	00	03	06
Elliott Lane	+1.1 - +2.8	0	-	-	-	0	0	0	0	0	0	-	-
Tinsley	+2.0 - +3.9	0	0	-	-	0	0	0	-	0	0	0	-
Prince of Wales	+2.0 - +3.9	-	-	-	-	0	-	-	-	-	-	-	-
Birley Moor	+2.0 - +3.9	-	-	-	-	-	-	-	-	-	-	-	-
Ringinglow	-0.9 - +1.4	0	0	0	0	0	0	0	0	0	0	0	0
Brad/Pros	+0.1 - +1.9	0	-	-	-	-	-	-	-	0	-	-	-
Hillfoot	+2.0 - +3.9	-	-	-	-	0	-	-	-	0	-	-	-

NOTES: 1) difference from Moscar Top, range accomodated by thermal map, + = sensor warmer than Moscar.
0 = within range
- = colder than thermal map (ie.nearer to Moscar temperature than predicted by thermal map)

Table 7.4: Possible Errors in Vehicle-Based Thermal Mapping

1. *EMISSIVITY OF ROAD SURFACE*
   The emissivity of the instrument can usually be varied, but an error of 1% = 0.5 deg.C (e.g. 0.95 instead of 0.96)

2. TEMPERATURE OF INSTRUMENT
   Infra-red thermometers are normally calibrated to operate within a certain instrument temperature range, this range may be exceeded

3. DETECTOR SENSITIVITY
   Instrument detectors will all respond slightly differently to give different signal/noise ratios

4. MILLIVOLT TO TEMPERATURE CONVERSION
   Errors in method e.g. regression

5. DIRTY LENS / CONDENSATION
   The lens of the instrument may become dirty due to splash and/or condensation may take place on the lens

6. ATMOSPHERIC ABSORPTION
   Not all radiation leaving the road surface will arrive at the instrument

7. VEHICLE RADIATION
   Radiation from the vehicle exhaust and/or engine may enter instrument

8. LENS WAVEBAND
   The lens is designed to only transmit a part of the infra-red spectrum

9. TYRE PRESSURE
   The distance covered between observations may vary between sampling runs due to differences in tyre circumference

10. LANE CHANGES
    The outside lane will be coldest due to less traffic, but most surveys are carried out on inside lane. Vehicles may have to move into different lanes on different surveys.

11. WARM-UP OF INSTRUMENT
    Some instruments require to be switched on up to an hour before use

Note: Systematic errors can be eliminated by careful preparation (e.g. 2,4,5,7,9) but the others may be random between surveys and different instruments.

SOURCE: Thornes, chapter 3 in Perry and Symons, 1991.

Table 7.5: Emissivity Values Applicable to Thermal Mapping

Source	Asphalt (Blacktop) Roads	Other Asphalt	Concrete	Water (pure)	Ice (clear/ smooth)	Frost (hoar/ rime)	Snow
LAND- tests on Sheffield samples	0.86,0.89,0.90(x5) 0.91,0.92(x2)						
LAND- pers.comm.				0.96	0.96	0.985	
LAND- tests for DTp	0.91-0.92 (3 samples)		0.88-0.89 (3 samples)				
Oke (1978)	0.95		0.71-0.90 (walls)	0.92-0.97			0.82-0.99
Blackmore (1982)	0.98-0.99 (11 samples)						
Used by Travers Morgan	0.96						
Used by (Vaisala) TMI	0.99						
Buettner and Kern (1965)		0.956 (paving)	0.966	0.993			
Lorenz (1966)	0.955		0.942				
AGA (1975)[1]			0.92	0.96	0.96 (-10°C)	0.98 (-10°C)	0.85 (-10°C)
Inframetrics[1] (1979)				0.95-0.96			
Kern (1964)[1]		0.967 (paving)					
Burch (1979)[1]		0.93-0.96	0.94	0.97	0.91	0.99	0.82
Woolley (1978)[1]		0.98(dry) 1.00(wet)					
Met. Office - pers. comm.	1.00 (wet/damp) 0.90 (dry)						

[1] from Marshall(1981)

Table 7.6: Calculated Errors in RST Readings

Temperature Regime °C (K)	Errors with emissivity set at 0.96 (°C and K)	
	True Emissivity	
	0.90	0.99
road = 0 (273) IRT = 6 (279) floor = 4 (277) exhaust = 100 (373)	+0.13	-0.22
road = 4 (277) IRT = 10 (283) floor = 8 (281) exhaust = 104 (377)	+0.11	-0.22
road = -4 (269) IRT = 2 (275) floor = 0 (273) exhaust = 96 (369)	+0.14	-0.22

Table 7.7: Average RSTs and Average Air Temperatures of Runs Along Route 1

Run	Air[1]	RST[2]	Difference[3]	Run	Air	RST	Difference
MOS2	4.85	2.5	-2.35	MS17	0.05	-2.3	-2.35
MOS3	2.25	0.2	-2.05	MS18	4.35	2.9	-1.45
MOS4	4.85	3.7	-1.15	MS19	6.65	5.1	-1.55
MOS5	8.1	6.3	-1.8	MS20	4.2	2.1	-2.1
MOS6	8.25	6.1	-2.15	MS21	3.2	0.7	-2.5
MOS7	9.25	7.6	-1.65	MS22	2.7	0.3	-2.4
MOS8	2.0	-0.6	-2.6	MS23	2.4	-0.3	-2.7
MOS9	3.5	1.3	-2.2	MS24	1.75	-0.2	-1.95
MOS10	0.75	-1.1	-1.85	MS25	6.05	3.7	-2.35
MOS11	-1.35	-3.7	-2.35	MS26	-1.35	-4.3	-2.95
MOS12	8.45	7.7	-0.75	MS27	-2.65	-5.4	-2.75
MOS13	6.9	6.2	-0.7	MS28	6.8	4.8	-2.0
MOS14	9.85	8.7	-1.15	MS29	-1.4	-3.4	-2.0
MOS15	7.0	5.6	-1.4	MS30	-0.25	0.4	+0.65
MOS16	4.8	2.6	-2.2	MS31	1.05	1.0	-0.05
MOS17	10.4	8.5	-1.9	MS32	-0.15	0.0	+0.15
MOS18	6.6	6.5	-0.1	MS33	0.4	0.4	0.0
MOS19	5.9	4.7	-1.2	MS34	-0.9	-0.7	+0.2
MOS20	8.7	8.4	-0.3	MS35	-0.5	-0.9	-0.4
MOS21	10.95	10.1	-0.85	MS36	-1.55	-4.5	-2.95
MOS22	5.55	5.6	+0.05	MS37	-3.2	-5.8	-2.6
MOS23	4.85	3.1	-1.75	MS38	0.8	-1.8	-2.6
MOS24	0.5	0.4	-0.1	MS39	1.95	0.6	-1.35
MOS25	10.05	11.4	+1.35	MS40	1.3	0.9	-0.4
MOS26	3.25	3.8	+0.55	MS41	-1.6	-3.6	-2.0
MOS27	-0.1	-0.2	-0.1	MS42	3.05	1.8	-1.25
MOS28	2.5	2.2	-0.3	MS43	5.8	4.5	-1.3
DV1B	0.5	-2.1	-2.6	MS44	2.0	0.3	-1.7
DV2B	4.85	3.3	-1.55	MS45	6.85	7.8	+0.95
DV3B	5.9	4.6	-1.3	MS46	2.15	0.2	-1.95
DV4B	10.05	9.0	-1.05	MS47	1.8	1.9	+0.1
DV5B	4.55	4.3	-0.25	MS48	2.0	-0.2	-2.2
DV6B	3.35	3.4	+0.05	MS49	8.4	6.5	-1.9
DV7B	-0.6	-0.6	0.0	MS50	6.25	6.9	+0.65
MS1	4.75	6.2	+1.45	MS51	6.35	6.7	+0.35
MS2	5.85	6.4	+0.55	MS52	7.0	5.6	-1.4
MS3	5.6	6.7	+1.1	MS53	8.3	8.2	-0.1
MS4	4.75	2.3	-2.45	MS54	10.95	11.3	+0.35
MS5	4.05	3.0	-1.05	MS55	6.4	7.4	+1.0
MS6	3.45	2.8	-0.65	MS56	9.5	8.6	-0.9
MS7	3.15	1.7	-1.45	MS57	8.2	7.4	-0.8
MS8	4.75	4.0	-0.75	MS58	5.2	5.0	-0.2
MS9	1.45	1.1	-0.35	MS59	4.5	5.2	+0.7
MS10	5.1	5.6	+0.5	MS60	3.55	4.1	+0.55
MS11	3.65	1.4	-2.25	MS61	3.9	4.2	+0.3
MS12	4.65	3.4	-1.25	MS62	2.9	2.8	-0.1
MS13	0.25	-1.0	-1.25	MS63	3.4	2.1	-1.3
MS14	3.3	2.1	-1.2	MS64	4.5	4.2	-0.3
MS15	3.65	1.3	-2.35	MS65	7.7	6.0	-1.7
MS16	2.75	2.3	-0.45	MS66	1.8	3.2	+1.4

NOTES: 1) average of measured start and end air temperatures
2) average of all RSTs for the run
3) RST-air, + indicates road warmer

APPENDIX 3

Table A3.1: Results of Calibration at Room Temperature

TEST	BSI TEMP. (°C)	Difference (+ = warmer than BSI) IRT (av.of 10) (°C)	Max/ min (°C)	TCa (°C)	TCb (°C)	TCc (°C)
1	21.5	-0.1	0.0	-0.2	-0.4	-0.4
2	21.6	-0.1	-0.1	-0.2	-0.1	-0.1
3	21.4	-0.1	0.1	0.0	-0.2	-0.2
4	21.6	-0.2	-0.1	-0.2	-0.4	-0.6
5	21.7	-0.1	-0.2	-0.1	-0.3	-0.4
	Average	-0.1	-0.1	-0.1	-0.3	-0.3

Table A3.2: Results of Calibration at 0°C

TEST	BSI TEMP. (°C)	Difference (+ = warmer than BSI) IRT (av. of 10) (°C)	TCa (°C)	TCb (°C)	TCc (°C)
1	0.0	0.1	0.4	0.2	0.0
2	0.0	0.0	0.5	0.2	0.1
3	0.0	-0.1	0.5	0.2	0.1
4	0.0	0.0	0.5	0.2	0.1
5	0.0	0.0	0.5	0.2	0.1
	Average	0.0	0.5	0.2	0.1

PhotoA3.1: Calibration Certificate for Compac 3 IRT

CERTIFICATE OF CONFORMITY

Land Infrared Ltd
Dronfield, Sheffield S18 6DJ
England
Telephone: (0246) 417691
Telex: 54457
Facsimile: (0246) 410585

Land Instruments Inc
2525 Pearl Buck Road
Bristol, PA 19007, USA
Telephone: (215) 781 0700
Telex: 831 392
Facsimile: (215) 781 0723

CERTIFICATE NUMBER

21331 R

Instrument Type : Minolta-hand - Cyclops compac 3.
Instrument Serial Number : 20002910
Condition on Receipt : Good
Faults Found : No Faults Found
Work Carried Out : Checked over Full Range - Reported Points
Date Completed : 16/06/89
New Parts Fitted : No Parts Fitted

Temperature	Error
0°C	0°C
22°C	0°C

Statement

This is to certify that the above returned instrument has been tested, examined and if necessary repaired and recalibrated against standards which are traceable to National and International Standards.
The instrument now conforms in all respects to the original specification and order requirements.

Signed for and on behalf of LAND ..... Land Calibration Laboratory

Photo A3.2: Calibration at Room Temperature

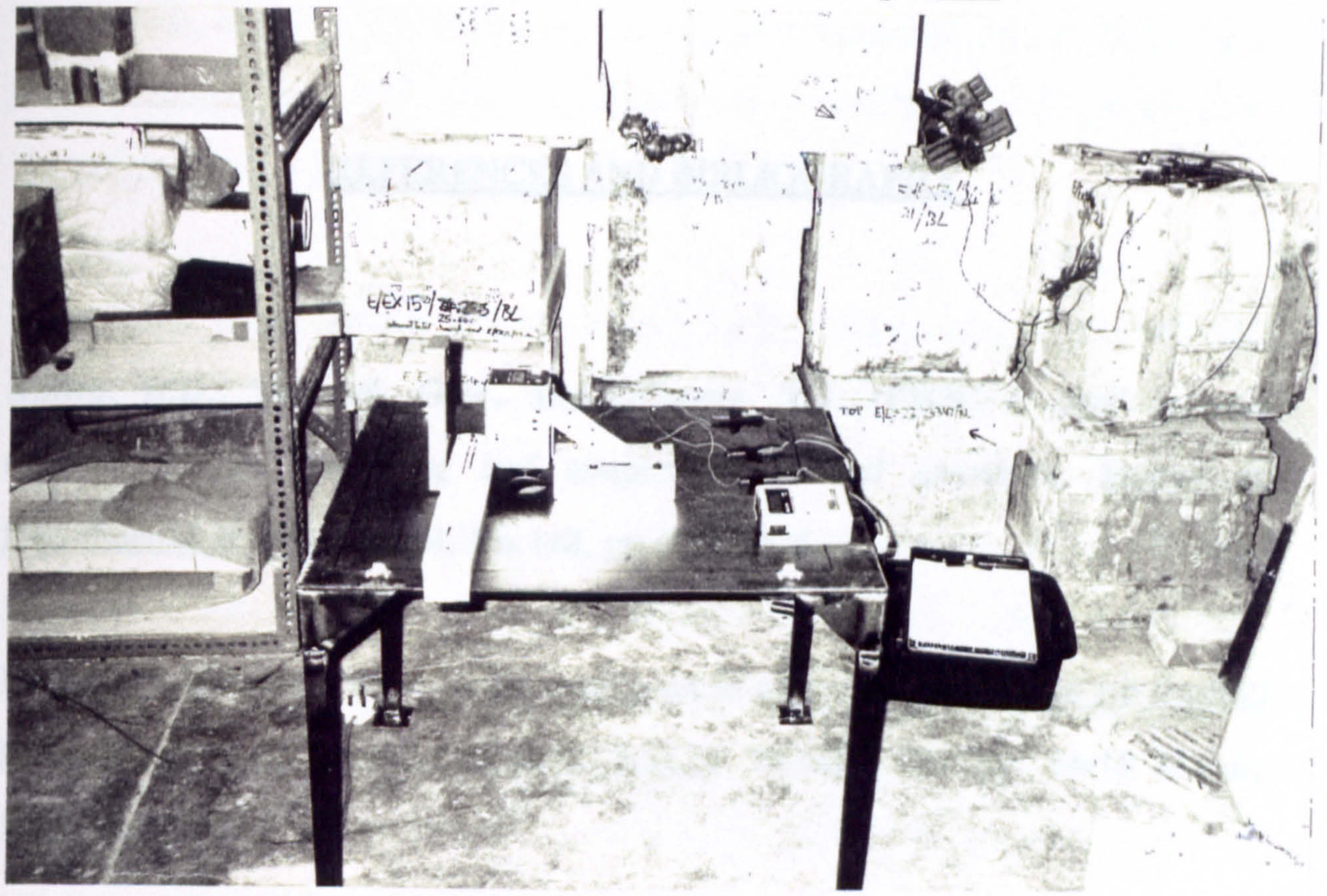


Photo A3.3: Calibration at 0.0°C

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Annual: 1988, 1989, 1990 and 1991.

Monthly: 1988, November and December.

1989, January-April, November and December.

1990, January-April, November and December.

1991, January-April.