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**Towed Thermistor Chain
Observations During MILE**

by

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and

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Office of Naval Research
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21. ABSTRACT (Continue on reverse side if necessary and identify by block number) Observations of temperature between 20 and 40 m depth were made with a towed thermistor chain in the North Pacific (50N, 145W) during the Mixed Layer Experiment (MILE). The chain was usually towed at a speed of 3 m/s around a 20 km square on alternate days for a three-week period beginning on 20 August 1977. The observations were averaged over sequential 30-second intervals and isotherm depths were interpolated from the averaged observations. Plots of temperature and isotherm depth are presented. The plots show the horizontal variability of temperature in the well-mixed layer and the vertical displacement		

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of isotherms induced by internal waves in the thermocline.

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INTRODUCTION

This report presents observations of temperature in the upper ocean obtained with a towed thermistor chain as a part of the Mixed Layer Experiment (MILE). The observations were taken between 20 and 40 m depth in the vicinity of Ocean Station P (50N, 145W) during August and September 1977. The thermistor chain was towed by the NOAA Ship OCEANOGRAPHER.

The temperature observations have been analyzed by Spoering (1979) to show the characteristics of internal waves in the upper ocean. Spoering's report also contains additional descriptions of the instrumentation, observations and analysis.

INSTRUMENTATION

The thermistor chain was constructed of sensors, conductors, plastic fairing, a strain member and a 450 kg. depressor. The thermistors were installed at 1 m intervals over a 25 m section of the chain. Four pressure sensors were installed at intervals of 8 m. The 450 kg. lead-filled depressor was attached to the lower end of the chain. The angle between the chain and the vertical was less than 10° for tow speeds up to 3 m/s with the depressor at a depth of 40 m. Signals from the sensors were recorded and displayed aboard ship by use of a minicomputer system.

OBSERVATIONS

The thermistor chain was usually towed on alternate days around a 20 km square. The tow tracks and times are presented in Appendix A. The tow beginning on 5 September proceeded four times around a five-km square centered on a heavily instrumented mooring. The tow tracks and speeds were determined from satellite fixes, radar fixes on the moorings and dead reckoning. During tows, the ships heading and speed were maintained as constant as possible on each leg. The tow speed ranged from 1 to 3 m/s and usually was greater than 2 m/s.

The structure of the upper ocean and the meteorological conditions were characteristic of mid-latitudes during late summer. The upper 30 m of the ocean was usually well-mixed or weakly stratified, bounded below by

a layer of large temperature gradient. Winds during the experiment ranged from near calm to 20 m/s. Wind speeds during tows of the thermistor chain ranged up to 12 m/s.

The only disappointment in the performance of the thermistor chain system was the failure of many of the temperature sensors. The failures were caused by saltwater leaks into the potting between the thermistors and the pad resistors and by leaks through the glass coatings of the thermistor. As a result of these failures only 4 to 10 thermistors were functional at any one time. The operational thermistors were concentrated in one section of the chain. This section was normally centered at a depth of about 30 m, in and above the region of high stratification.

ANALYSIS

The temperature observations were low-pass filtered by computing sequential 30 s averages. The filtered observations were edited to remove effects of radio noise and other errors. These filtered and edited observations are shown in Appendix B as functions of time and distance during a tow.

Isotherm depths were determined by linear interpolation between the filtered temperature observations. The depths of isotherms at spacings of 0.5°C are shown in Appendix C as functions of time and distance during a tow. Some of the tows are also plotted with a 1.0°C spacing in Appendix D.

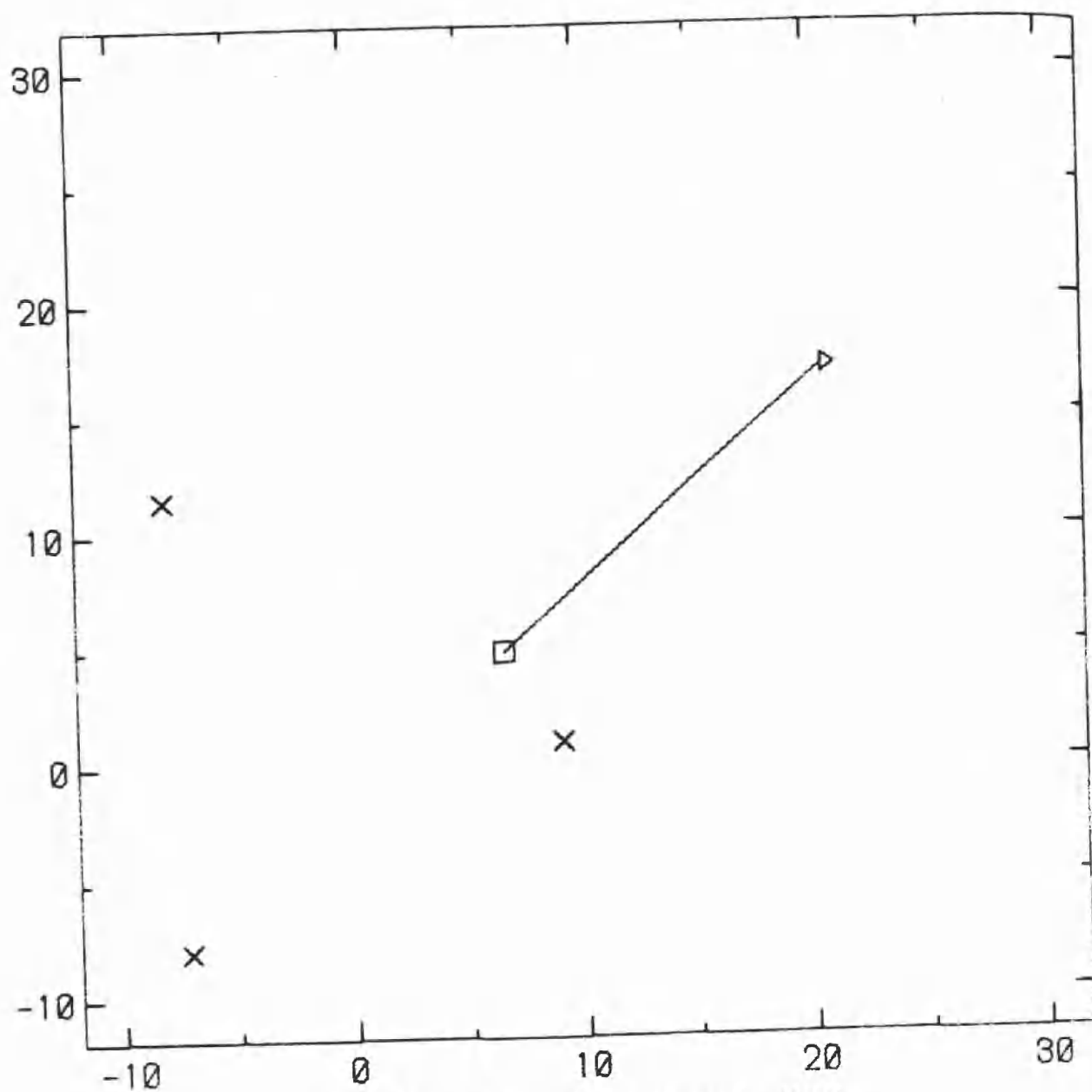
REFERENCES

- Spoering, T. J., 1979: Towed observations of internal waves in the upper ocean. Report 79-10, School of Oceanography, Oregon State University, Corvallis, OR 97331, 121 pp.

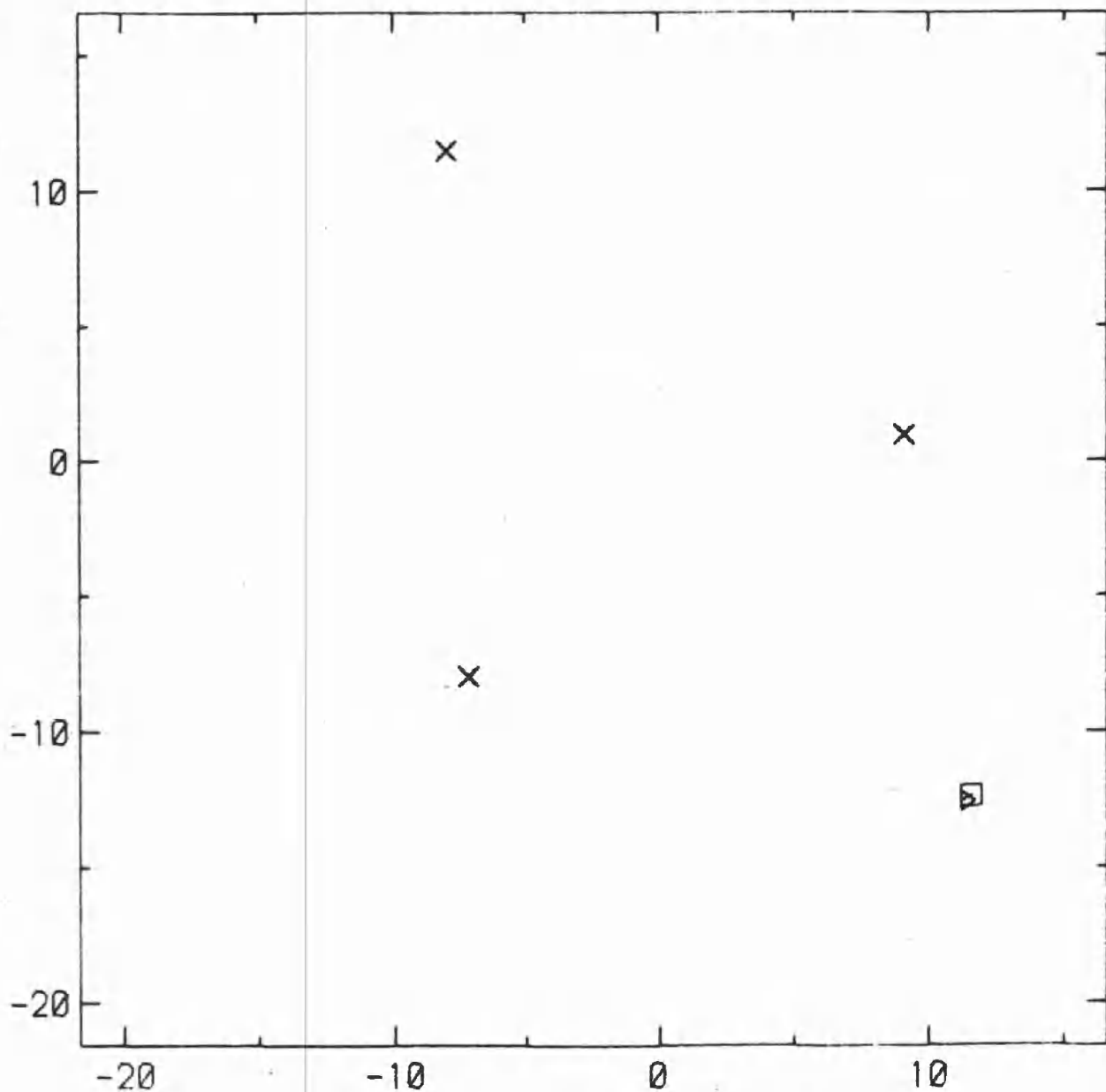
APPENDIX A

Tow Tracks

Tow tracks are shown on the following pages for all of the runs. The origin of the coordinate system is at $49^{\circ} 43.31'N$, $145 W$. The abscissa and ordinate are in kilometers displacement to the east and north, respectively. The locations of each of the moorings are shown by an X. The southern mooring was the most heavily instrumented, primarily with VACMs. The northern mooring was instrumented by R. Davis with propeller-type current meters. The eastern mooring consisted of a wave-rider.



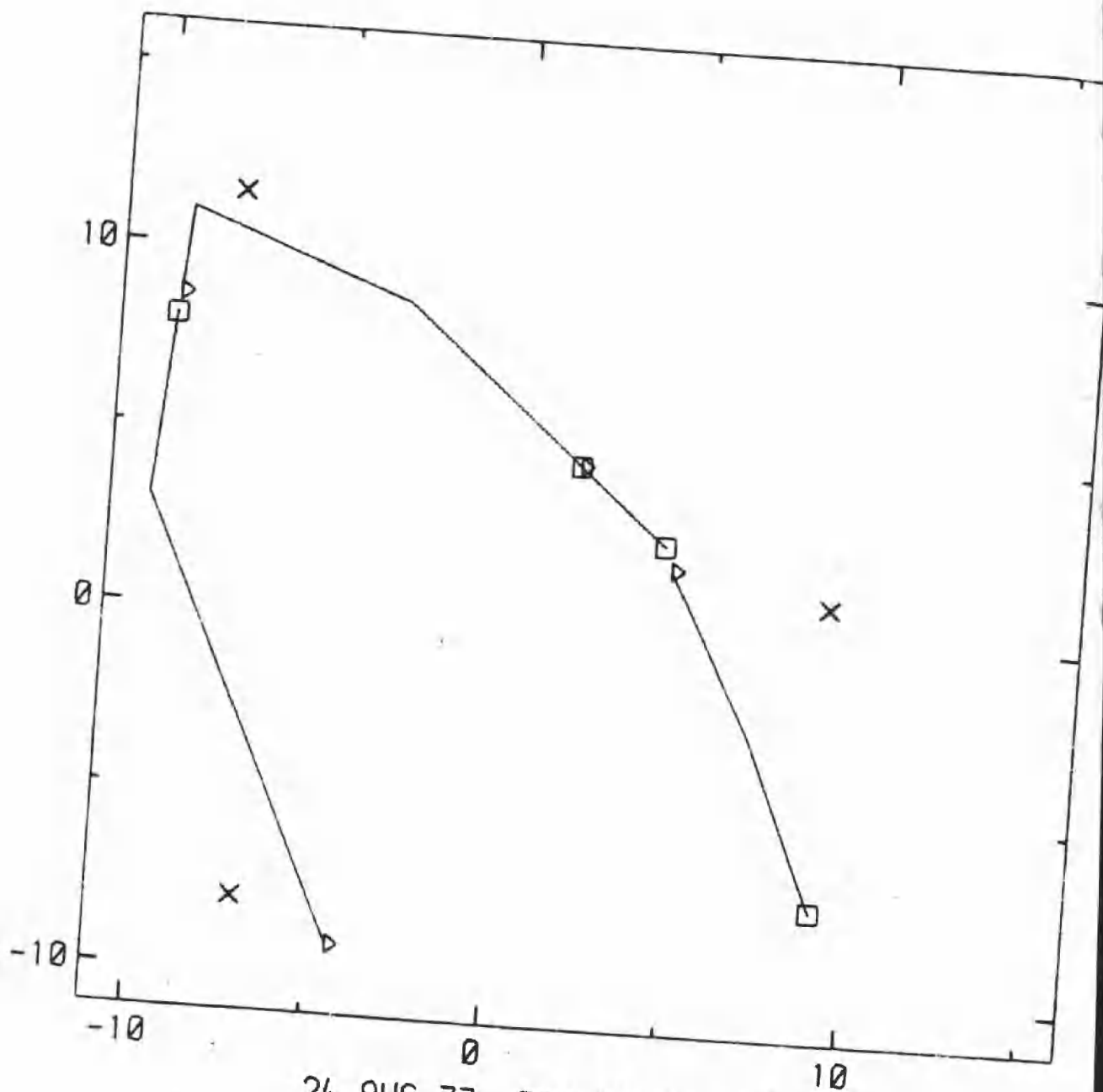
20 AUG 77 TOW TRACKS (KM)
RUN 01 1846 TO 2201 GMT
□: BEGINNING ▷: END ×: MOORING



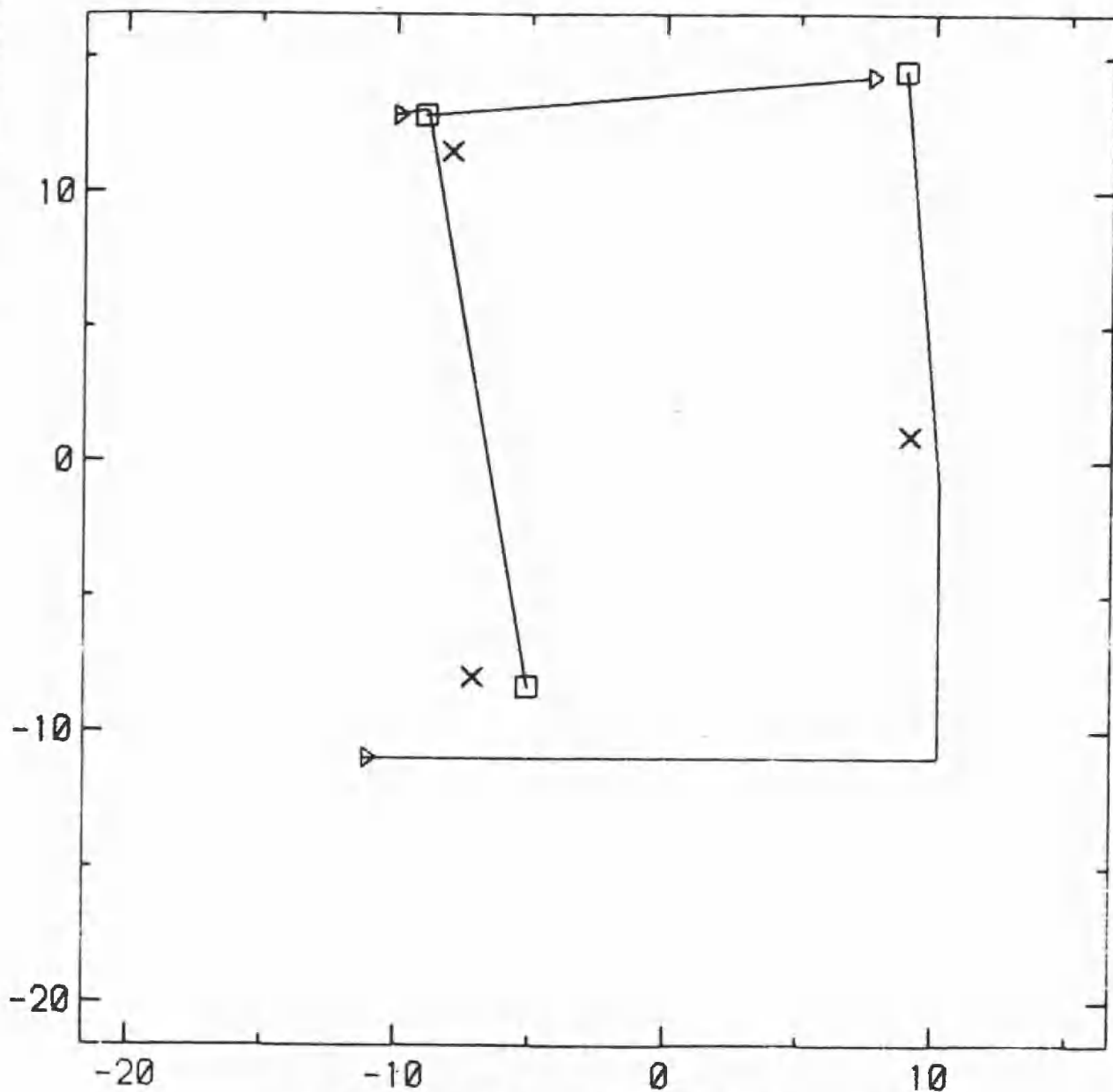
22 AUG 77 TOW TRACKS (KM)

RUN 02 1648 TO 1654 GMT

□: BEGINNING ▷: END x: MOORING



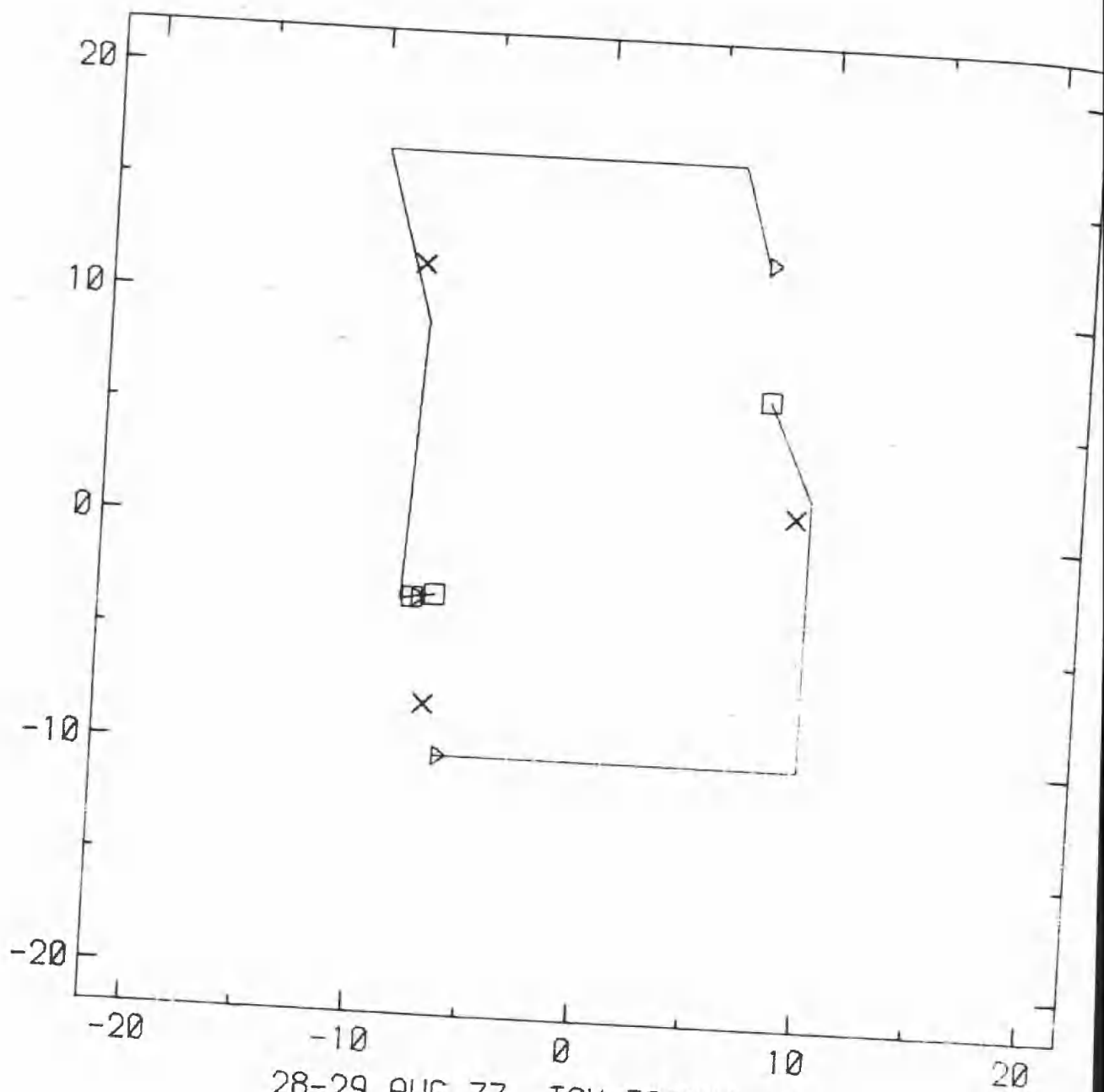
24 AUG 77 TOW TRACKS (KM)
 RUNS 03-06 1654 TO 1848 GMT
 □: BEGINNING ▷: END x: MOORING



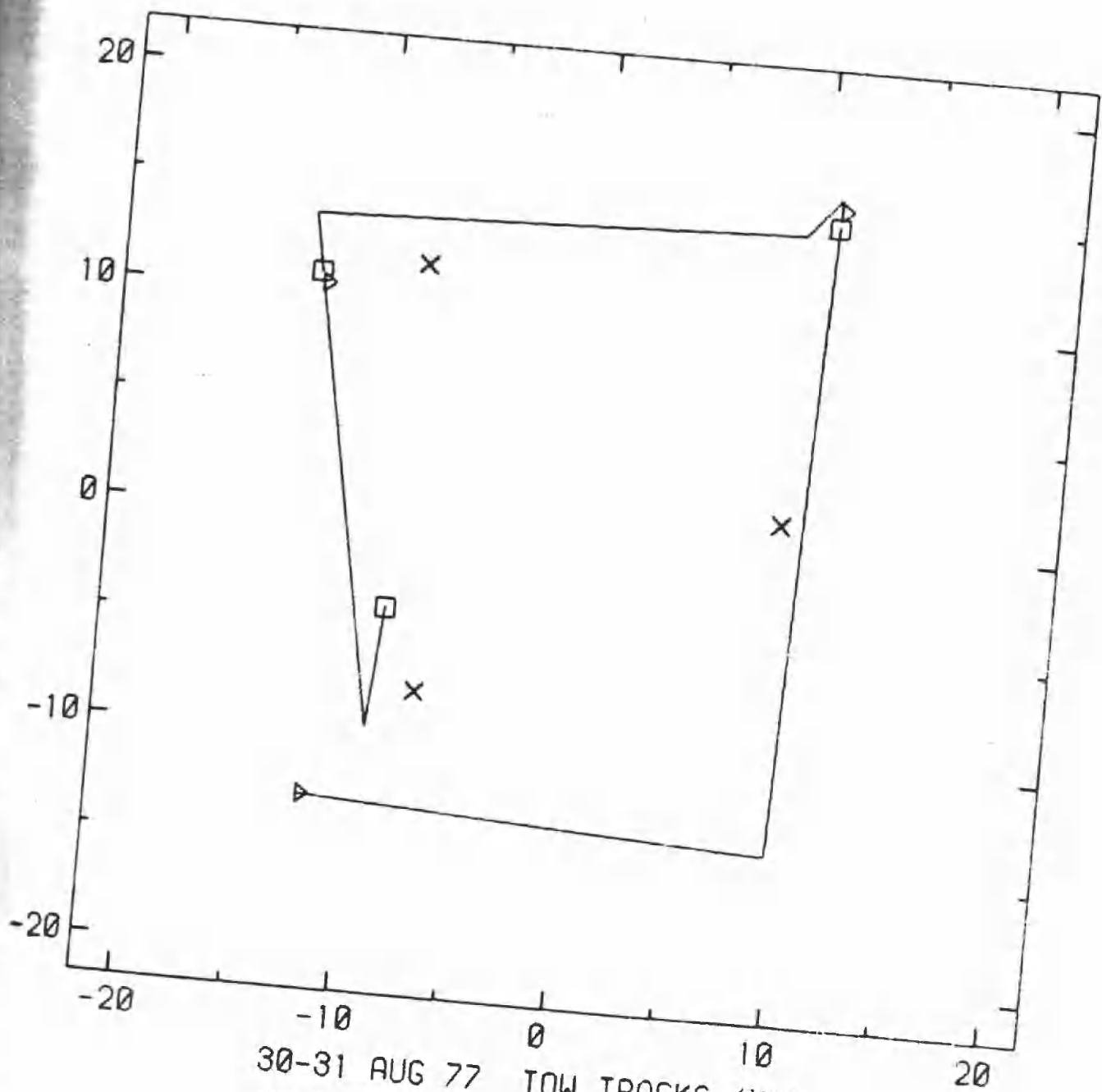
26-27 AUG 77 TOW TRACKS (KM)

RUN 07-09 1521 TO 0028 GMT

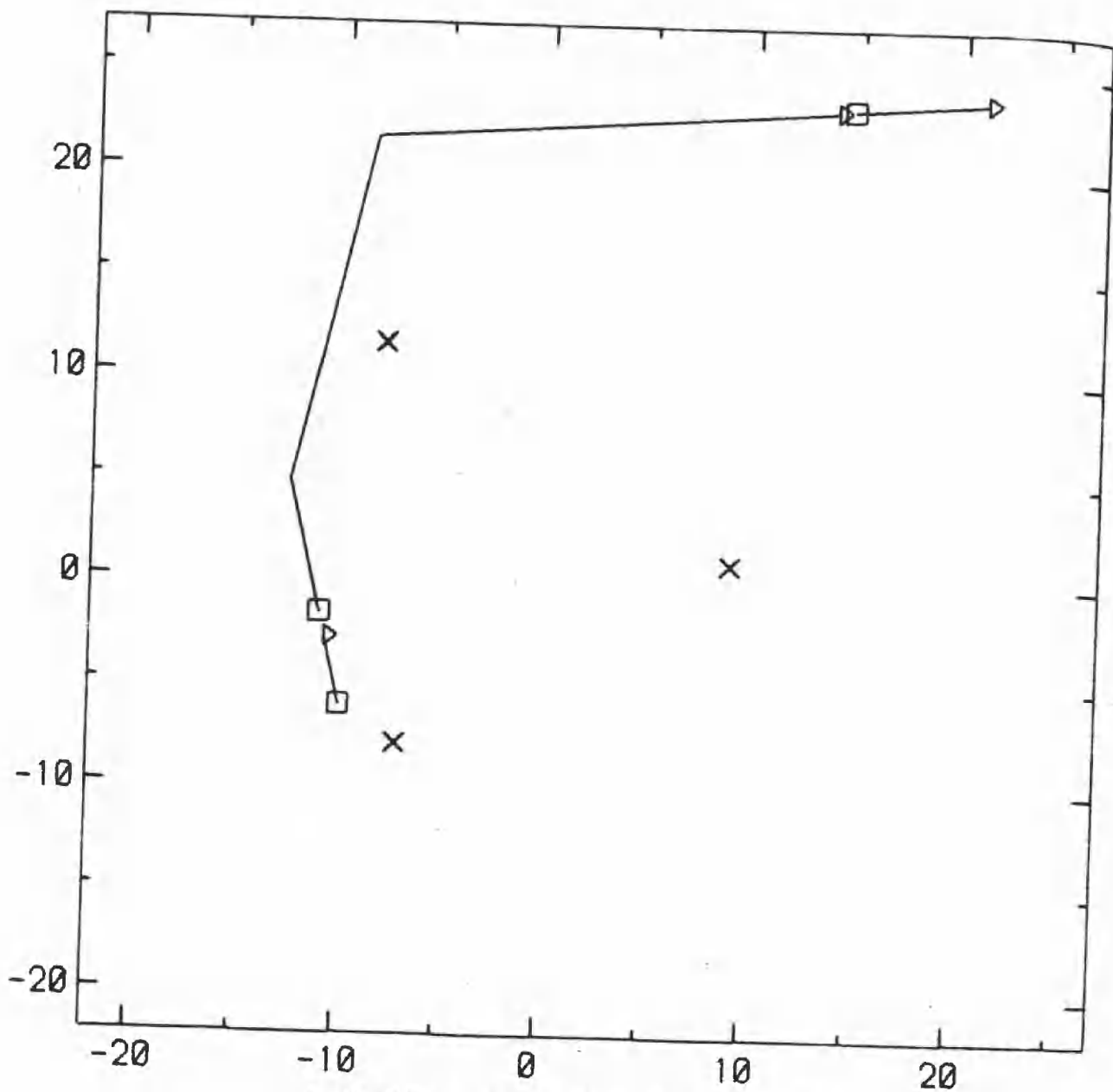
□: BEGINNING ▷: END x: MOORING



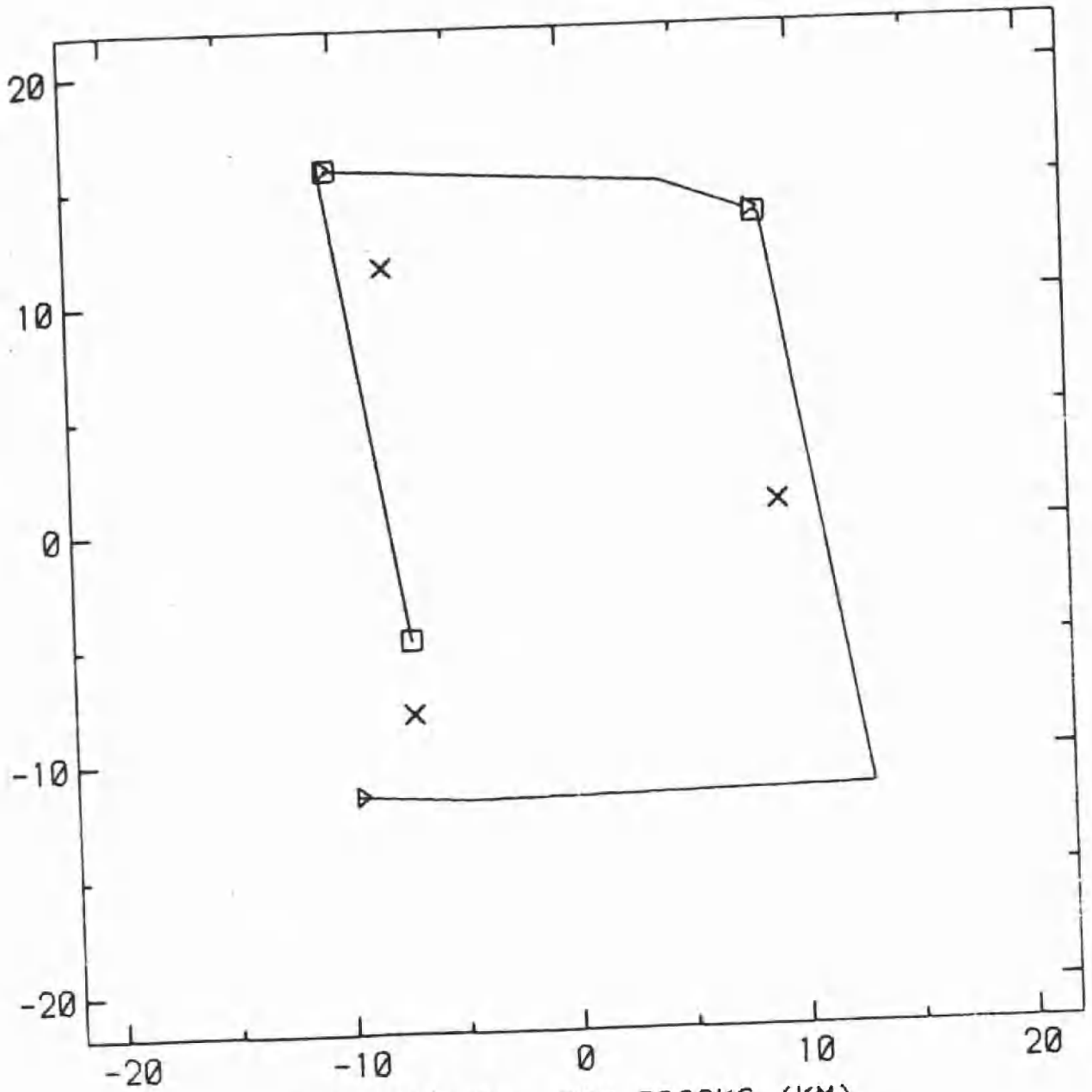
28-29 AUG 77 TOW TRACKS (KM)
 RUNS 10-12 1515 TO 0119 GMT
 □: BEGINNING ▷: END ×: MOORING



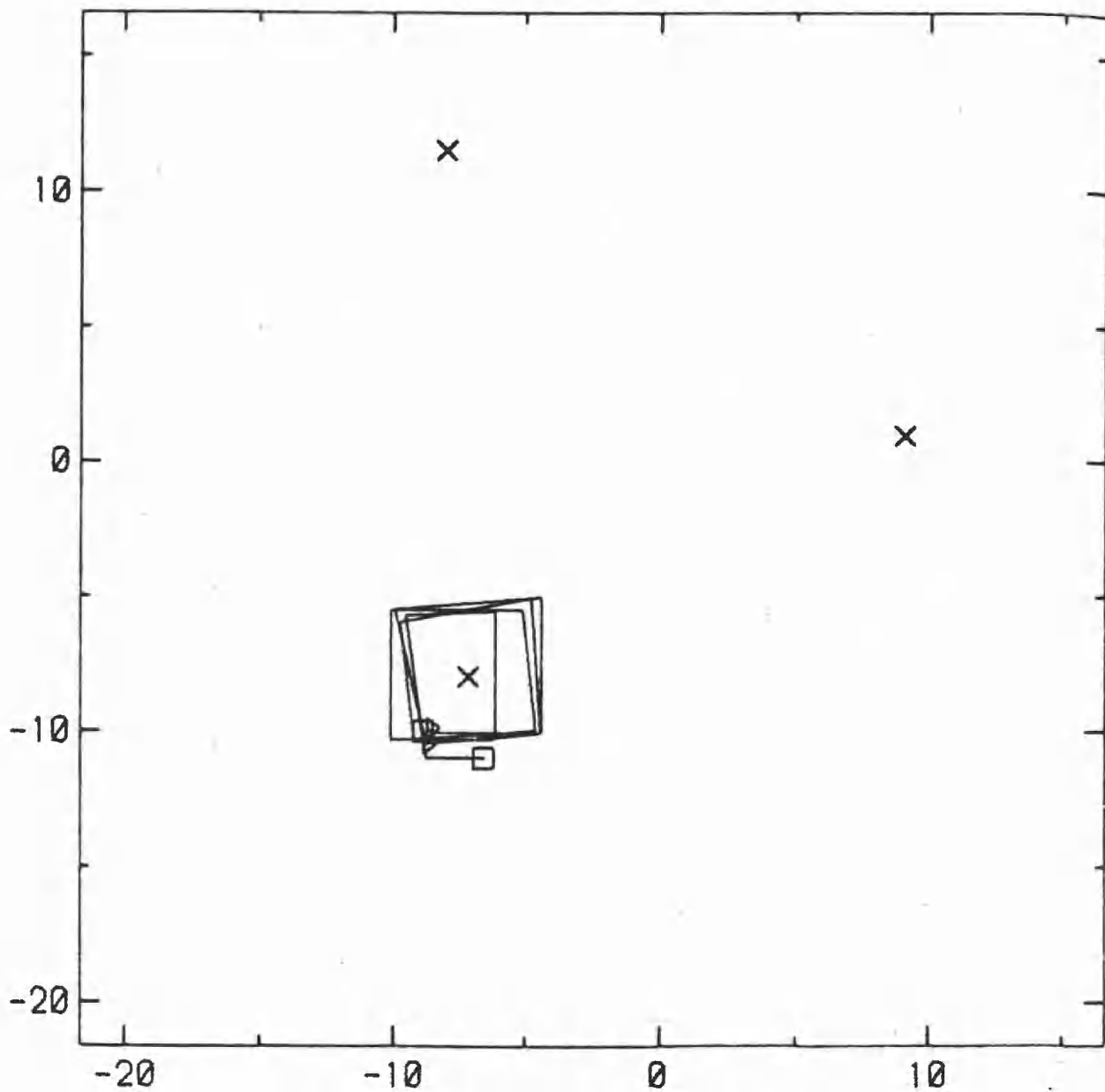
30-31 AUG 77 TOW TRACKS (KM)
 RUNS 13-15 1736 TO 0328 GMT
 □: BEGINNING ▷: END X: MOORING



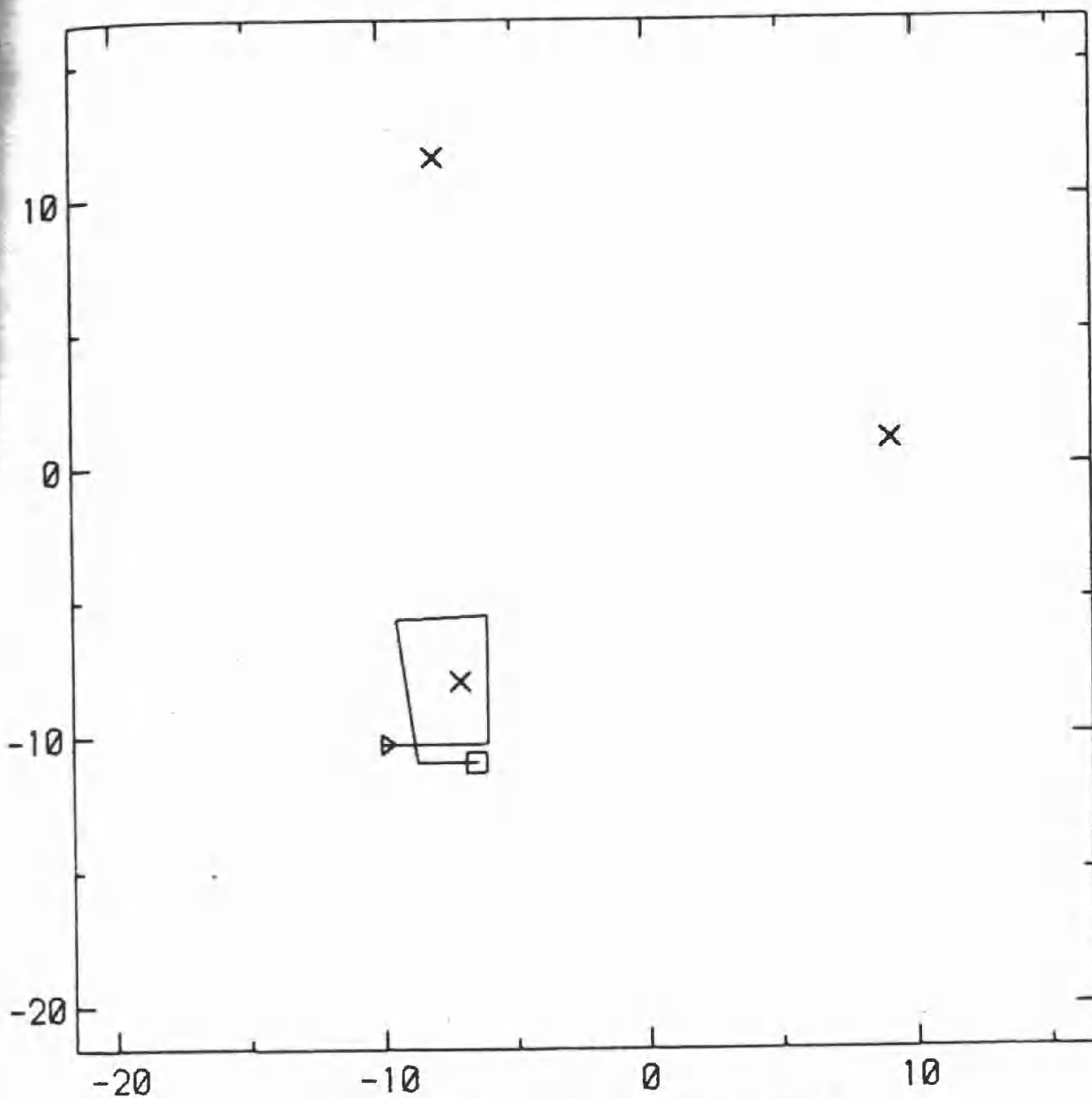
1-2 SEP 77 TOW TRACKS (KM)
 RUNS 16-18 1723 TO 0052 GMT
 □: BEGINNING ▷: END x: MOORING



3-4 SEP 77 TOW TRACKS (KM)
 RUNS 19-21 1811 TO 0259 GMT
 □: BEGINNING ▷: END x: MOORING



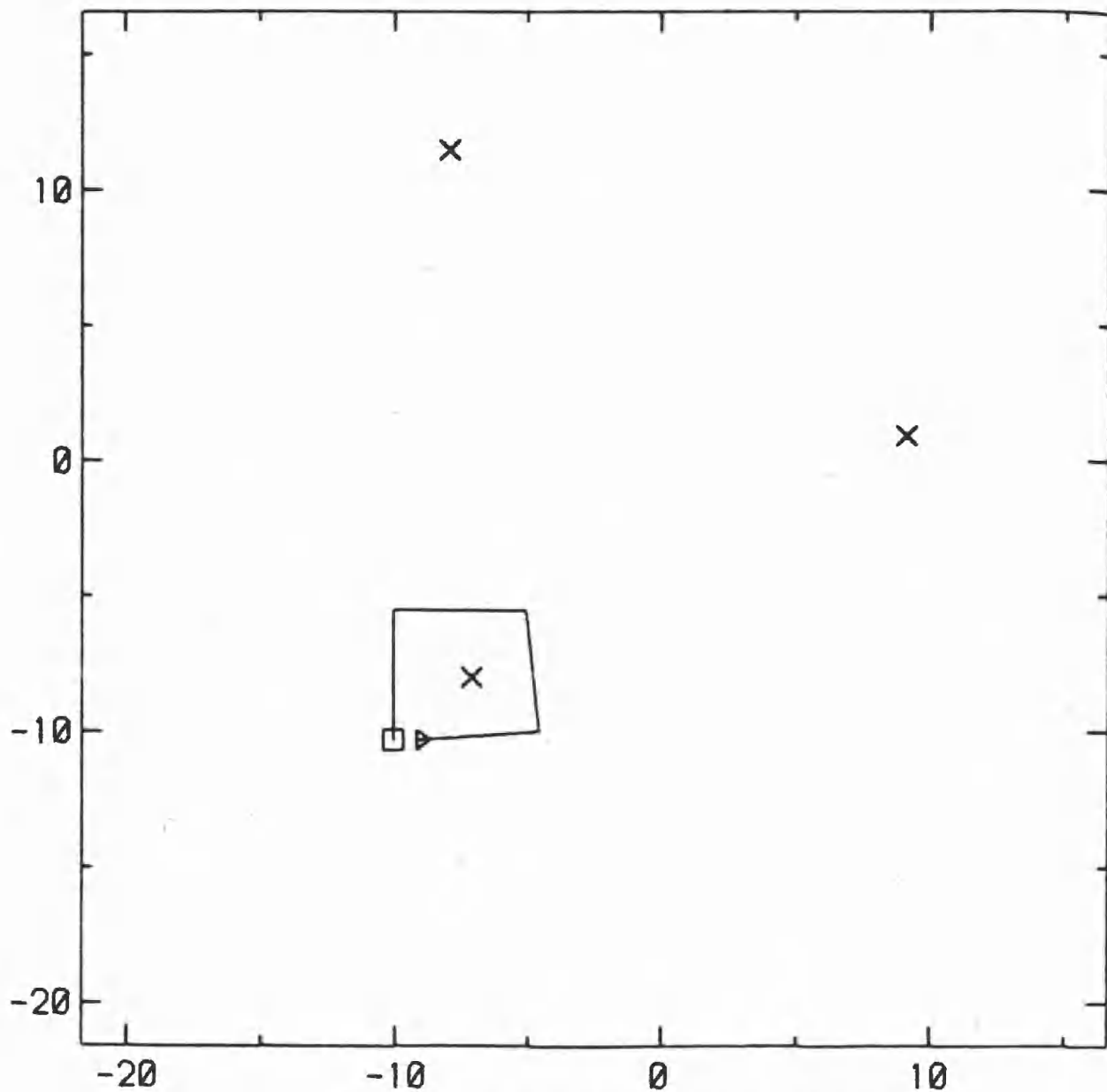
5-6 SEP 77 TOW TRACKS (KM)
 RUNS 22-23 1817 TO 0227 GMT
 □: BEGINNING ▸: END x: MOORING



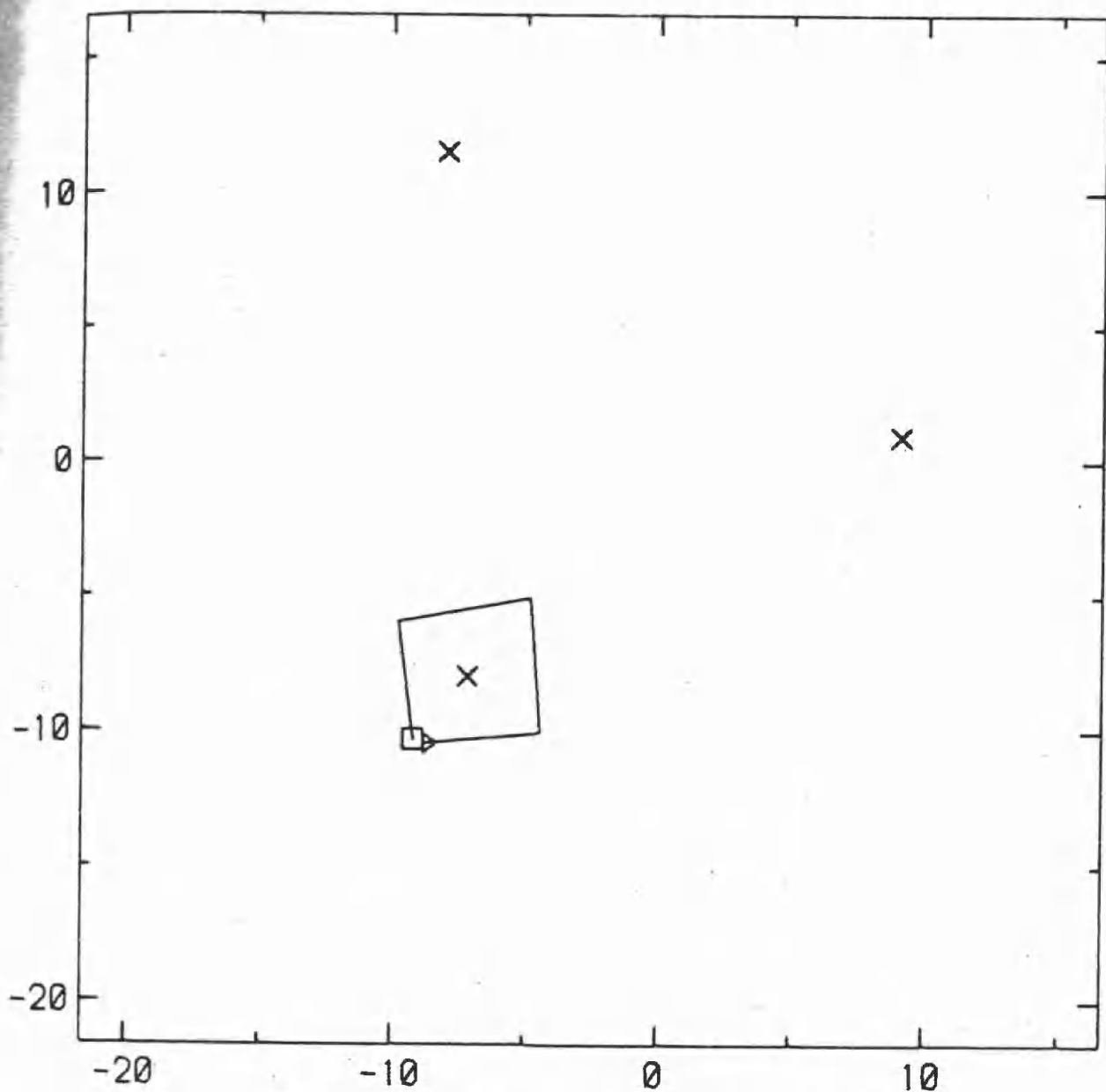
5 SEP 77 TOW TRACKS (KM)

RUN 22 1817 TO 2027 GMT

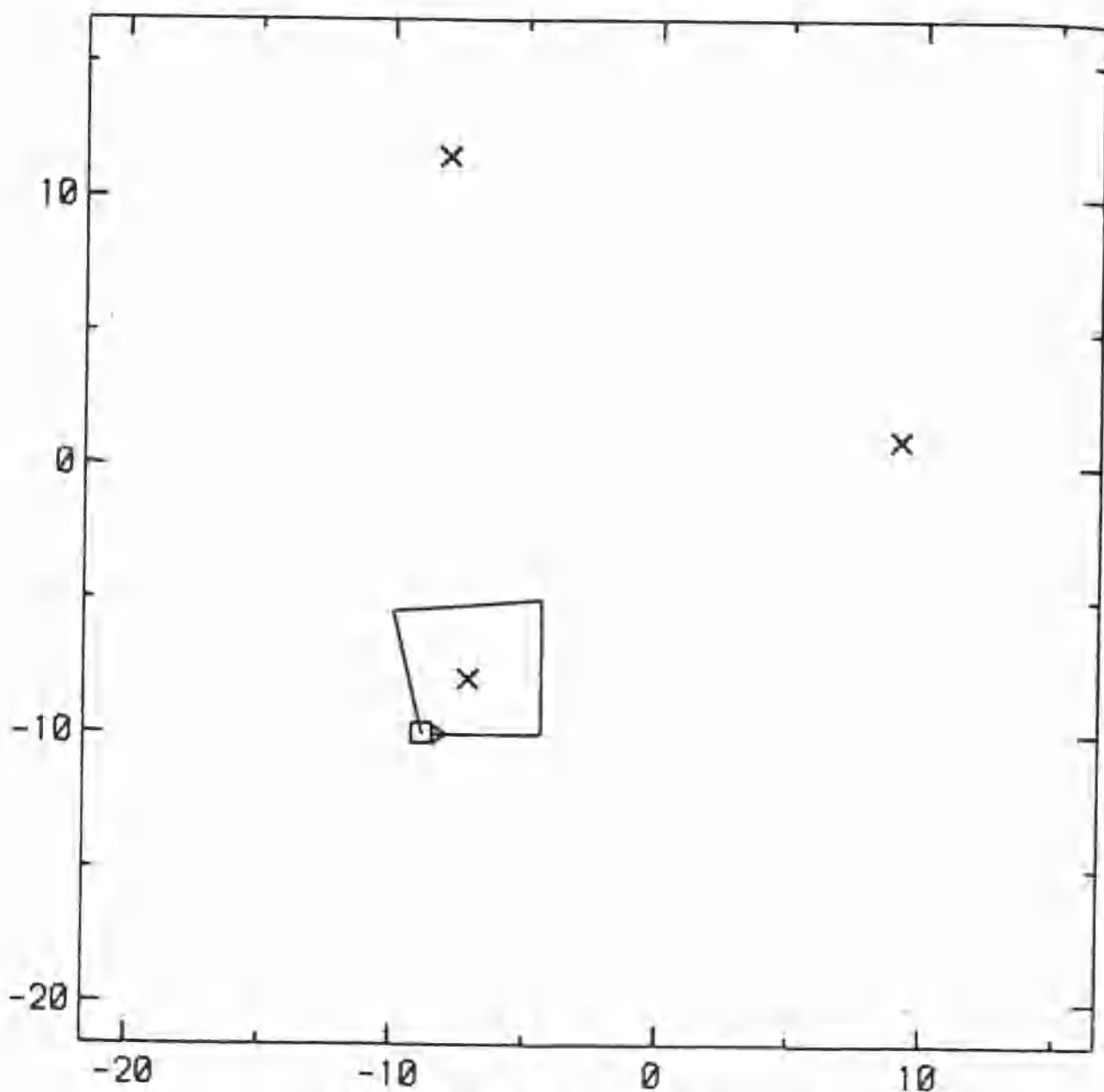
□: BEGINNING ▷: END ×: MOORING



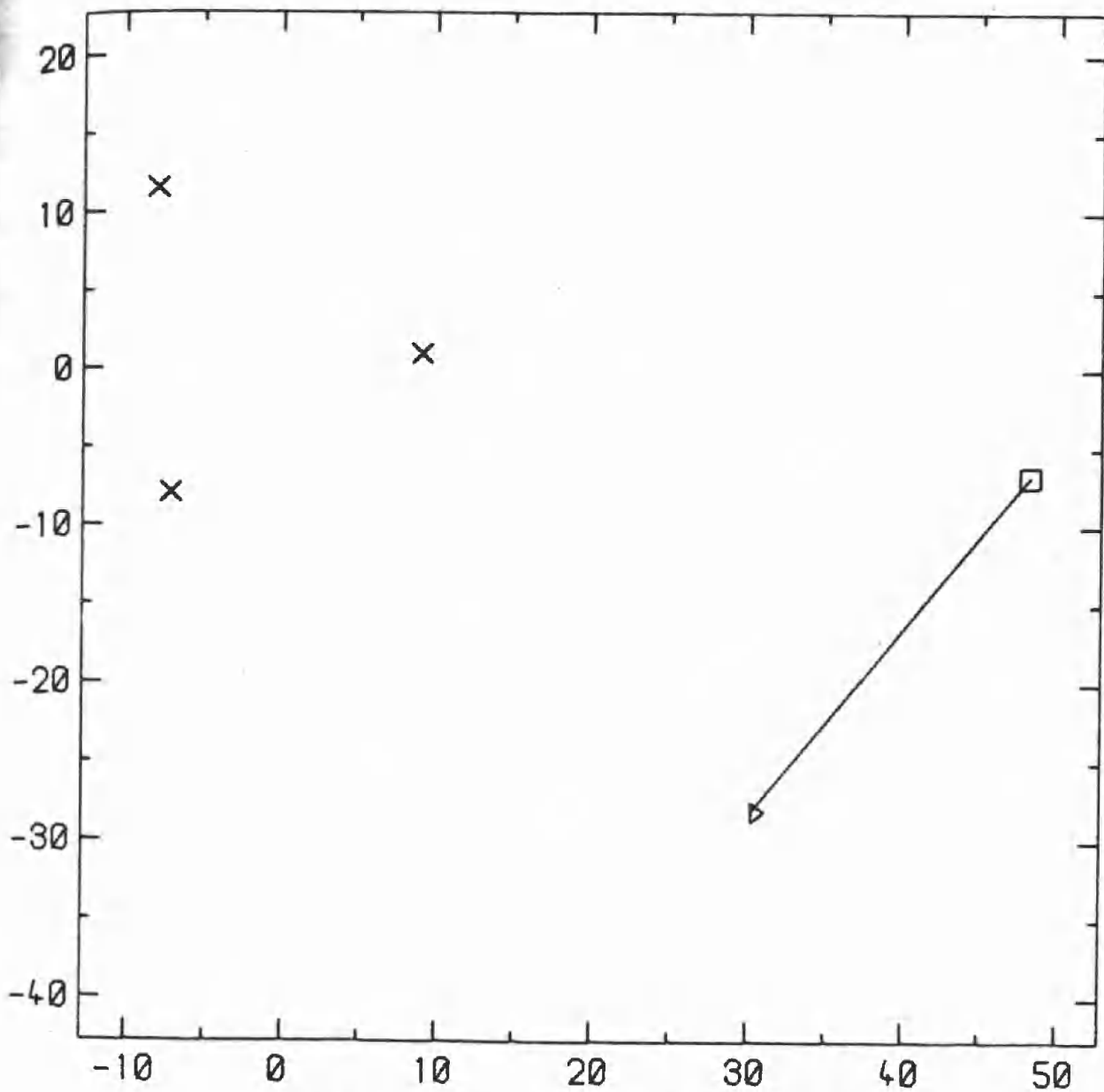
5 SEP 77 TOW TRACKS (KM)
RUN 22 2027 TO 2225 GMT
□: BEGINNING ▷: END x: MOORING



5-6 SEP 77 TOW TRACKS (KM)
RUN 22 2225 TO 0028 GMT
□: BEGINNING ▷: END x: MOORING



6 SEP 77 TOW TRACKS (KM)
 RUN 23 0031 TO 0229 GMT
 □: BEGINNING ▷: END x: MOORING

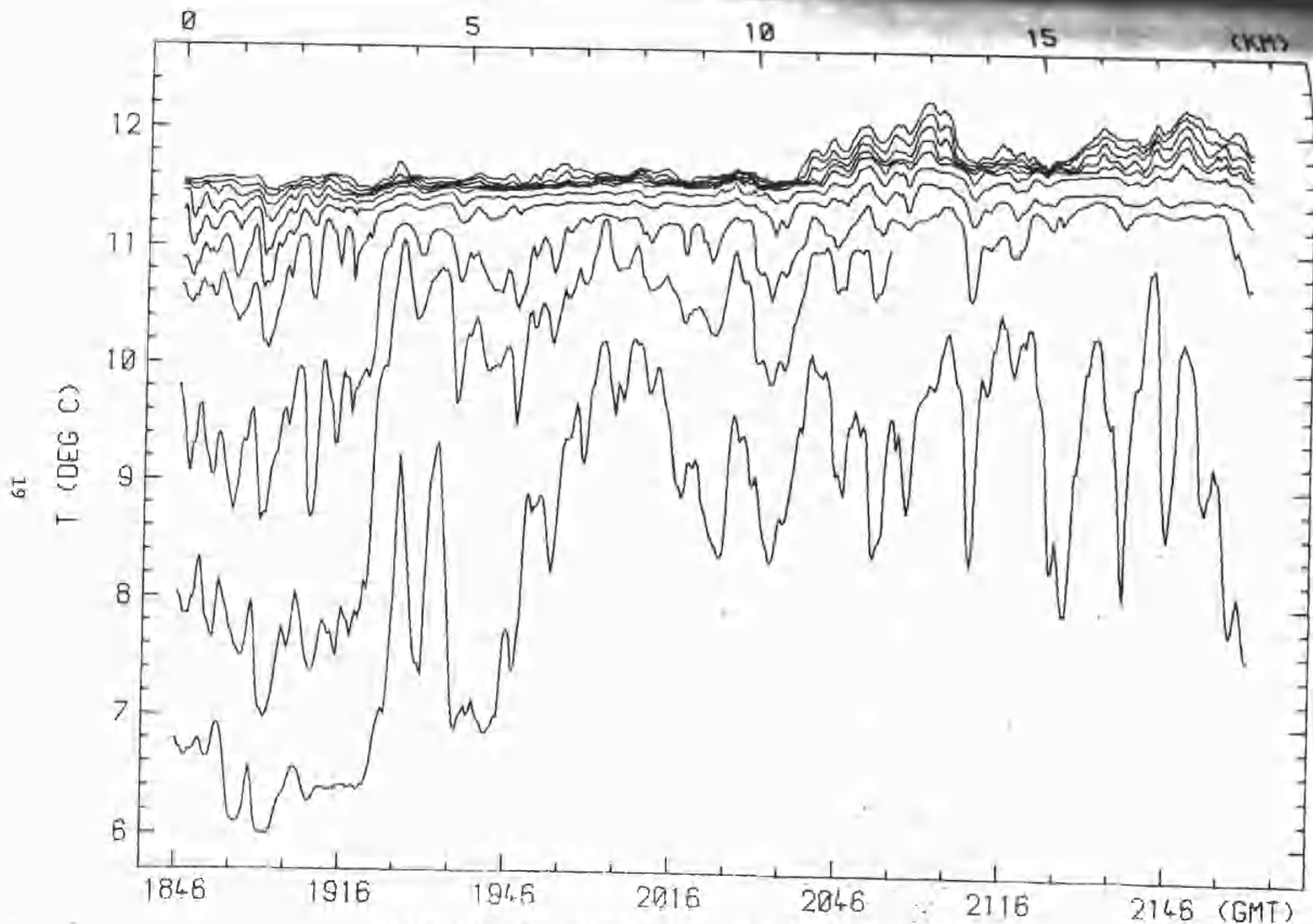


8 SEP 77 TOW TRACKS (KM)
RUN 24 1814 TO 2107 GMT
□: BEGINNING ▷: END X: MOORING

APPENDIX B

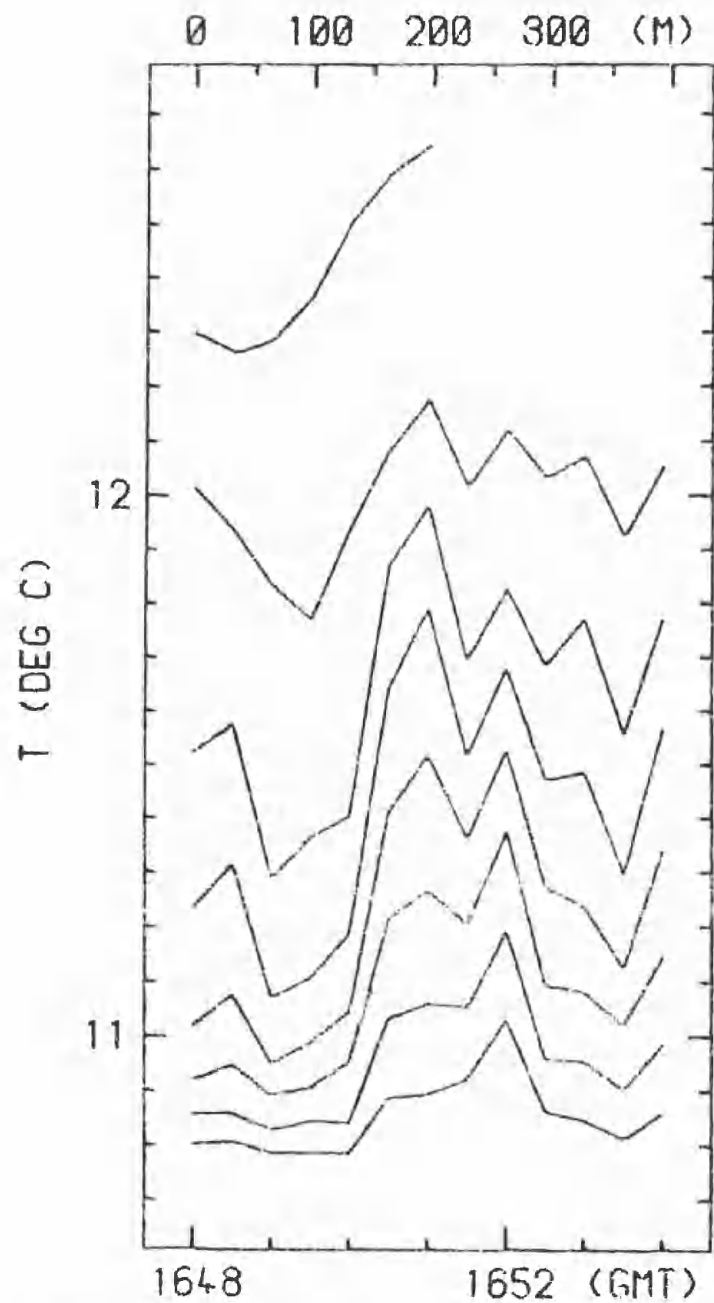
Temperature Cross-sections

Temperature averaged over sequential 30 s intervals are plotted on the following pages.



RUN 01 20 AUG 77 TEMP VS TIME/DISTANCE

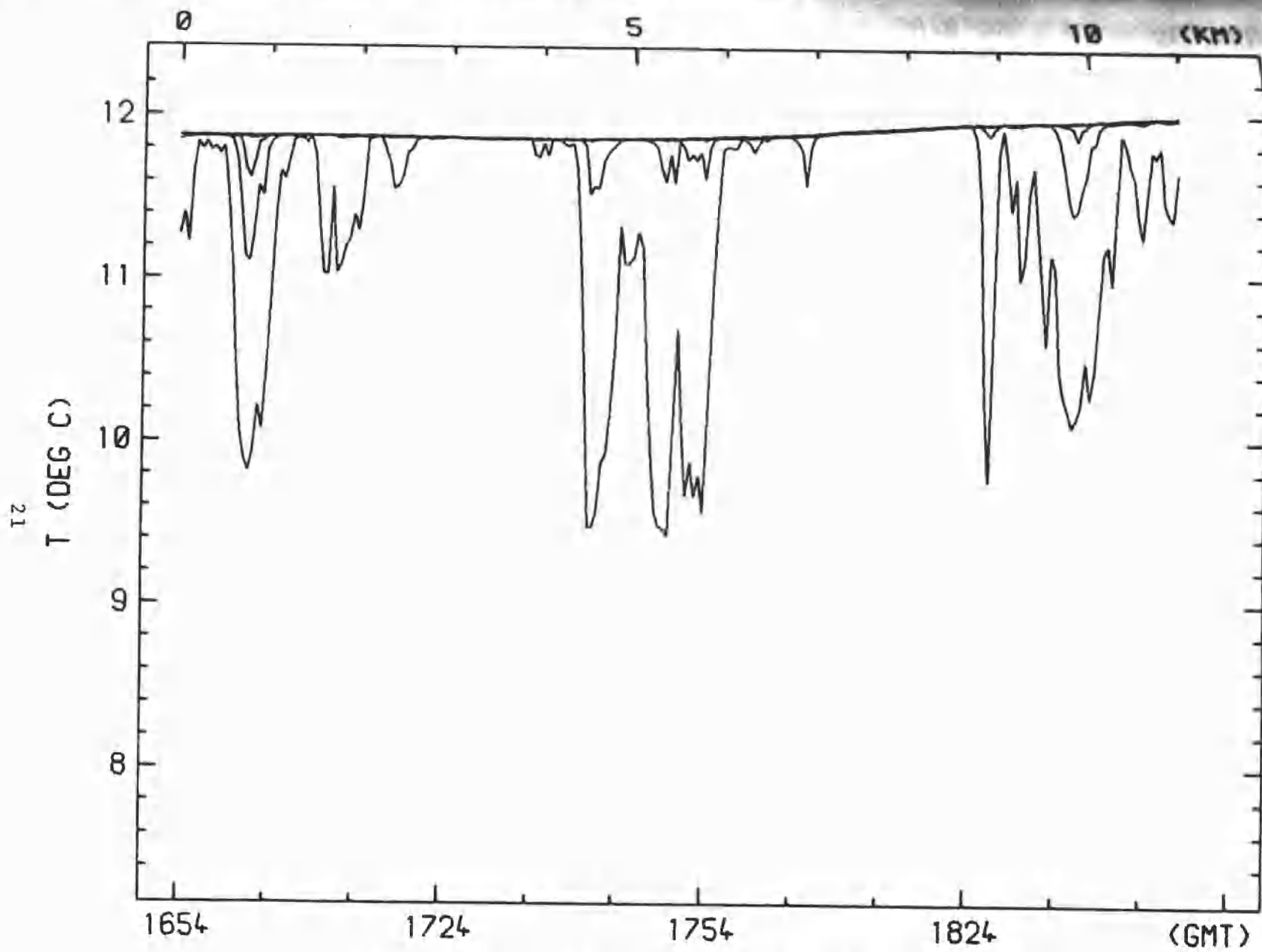
DEPTH = 22.7, 23.8, 24.8, 25.9, 26.9, 28.0, 29.0, 32.2, 35.3, 41.6 M



RUN 02 22 AUG 77 TEMP VS TIME/DISTANCE

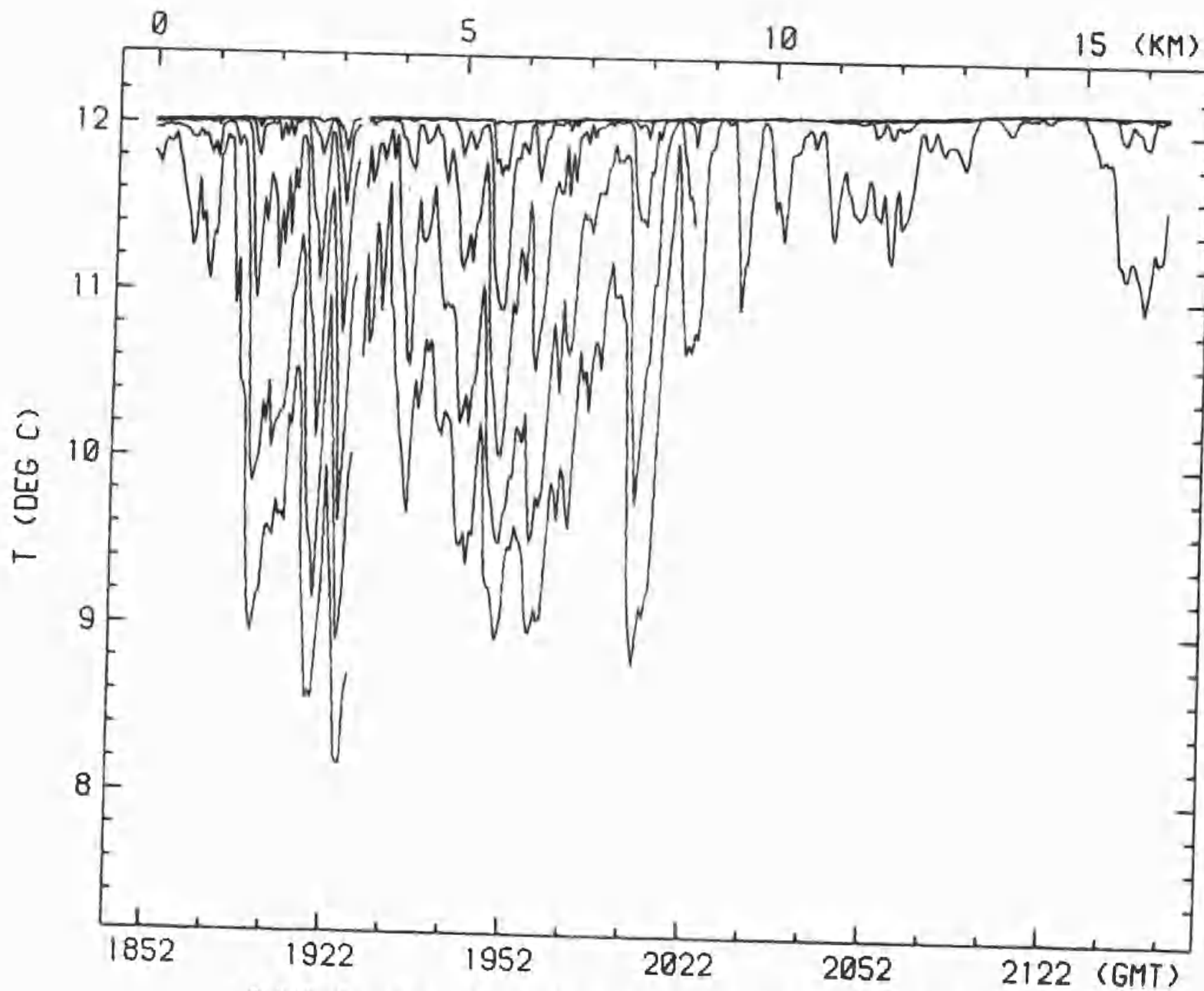
DEPTH = 21 7.22 7.24 8.25 9.26 9.28 9.29 9.30 1 M

DEPTH = 21.7, 22.7, 24.8, 25.9, 26.9, 28.0, 30.1 M



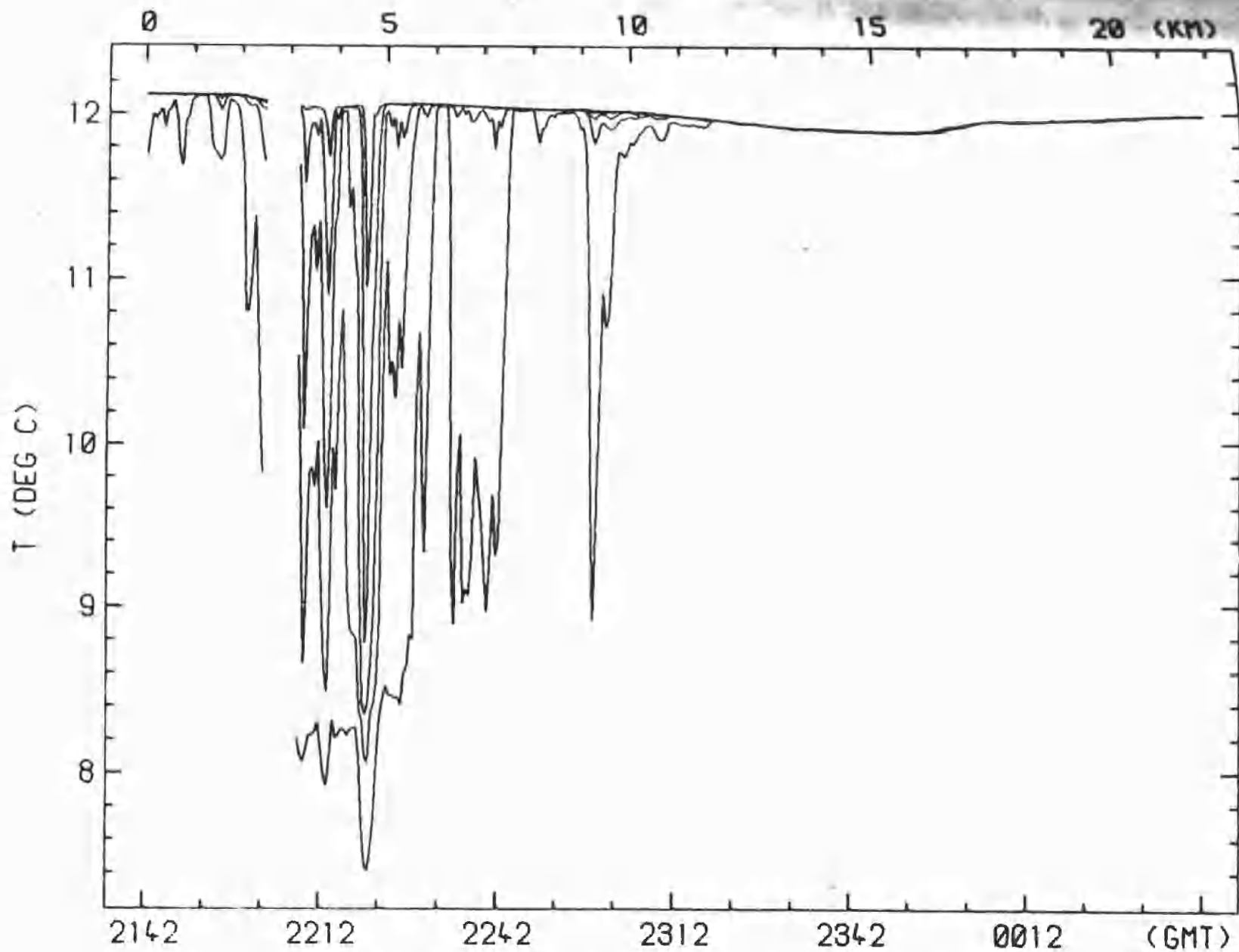
RUN 03 24 AUG 77 TEMP VS TIME/DISTANCE

DEPTH = 24.8, 25.9, 26.9, 28.0, 30.1 M



RUNS 04-05 24 AUG 77 TEMP VS TIME/DISTANCE

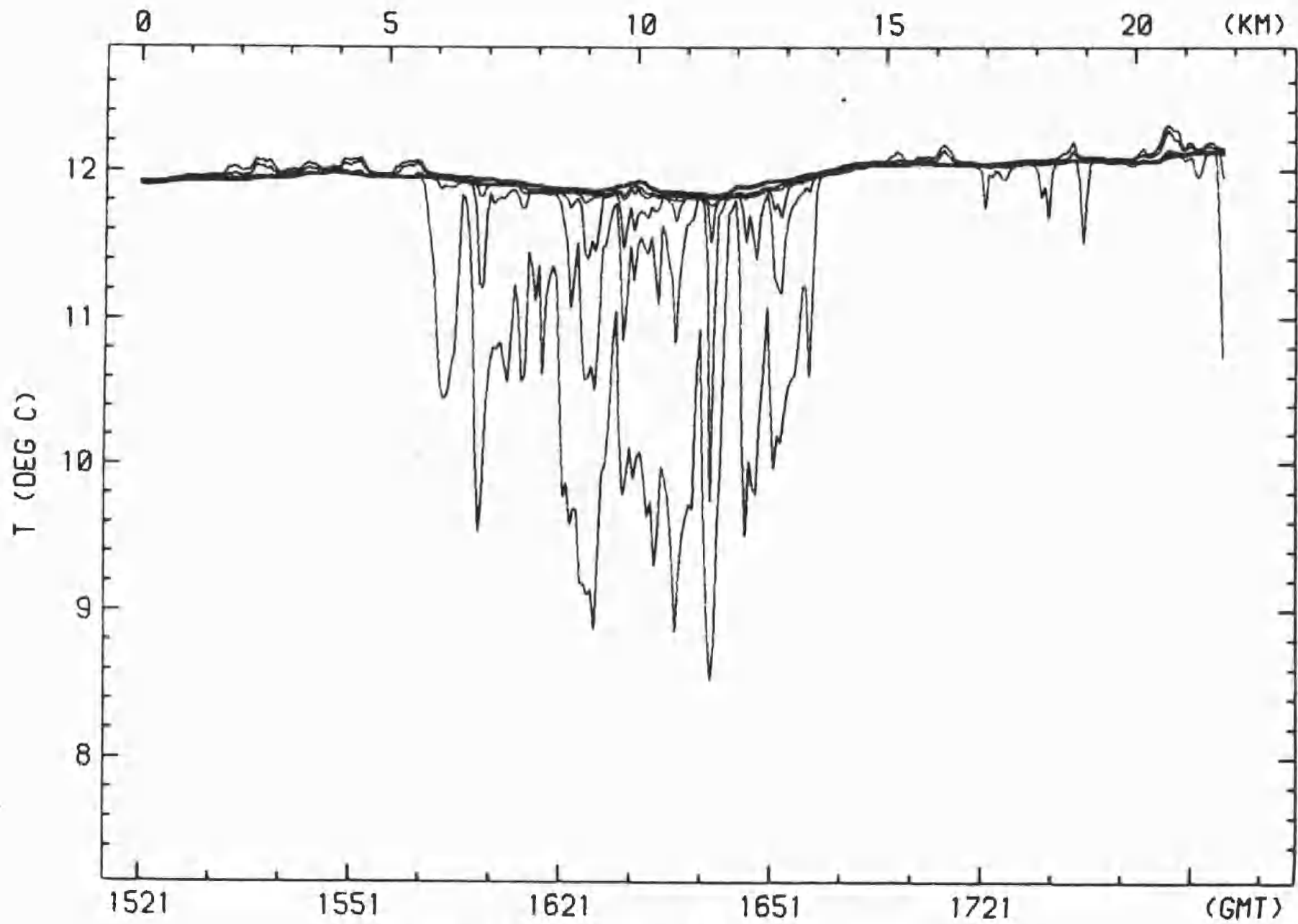
DEPTH = 24.8, 25.9, 26.9, 28.9, 29.0, 30.1



RUNS 05-06 24 AUG 77 TEMP VS TIME/DISTANCE

DEPTH = 24.8, 25.9, 26.9, 28.0, 30.1 M

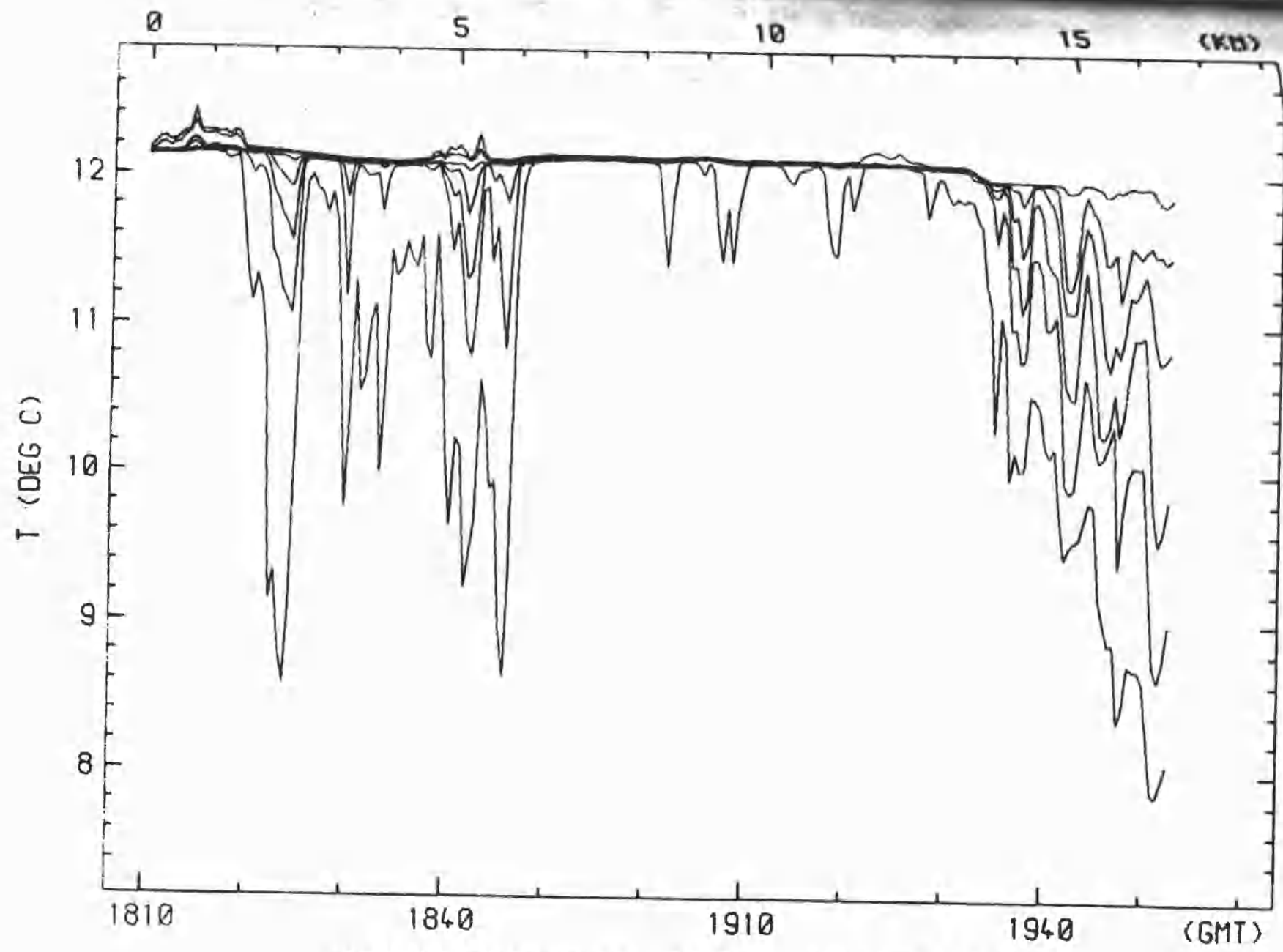
24



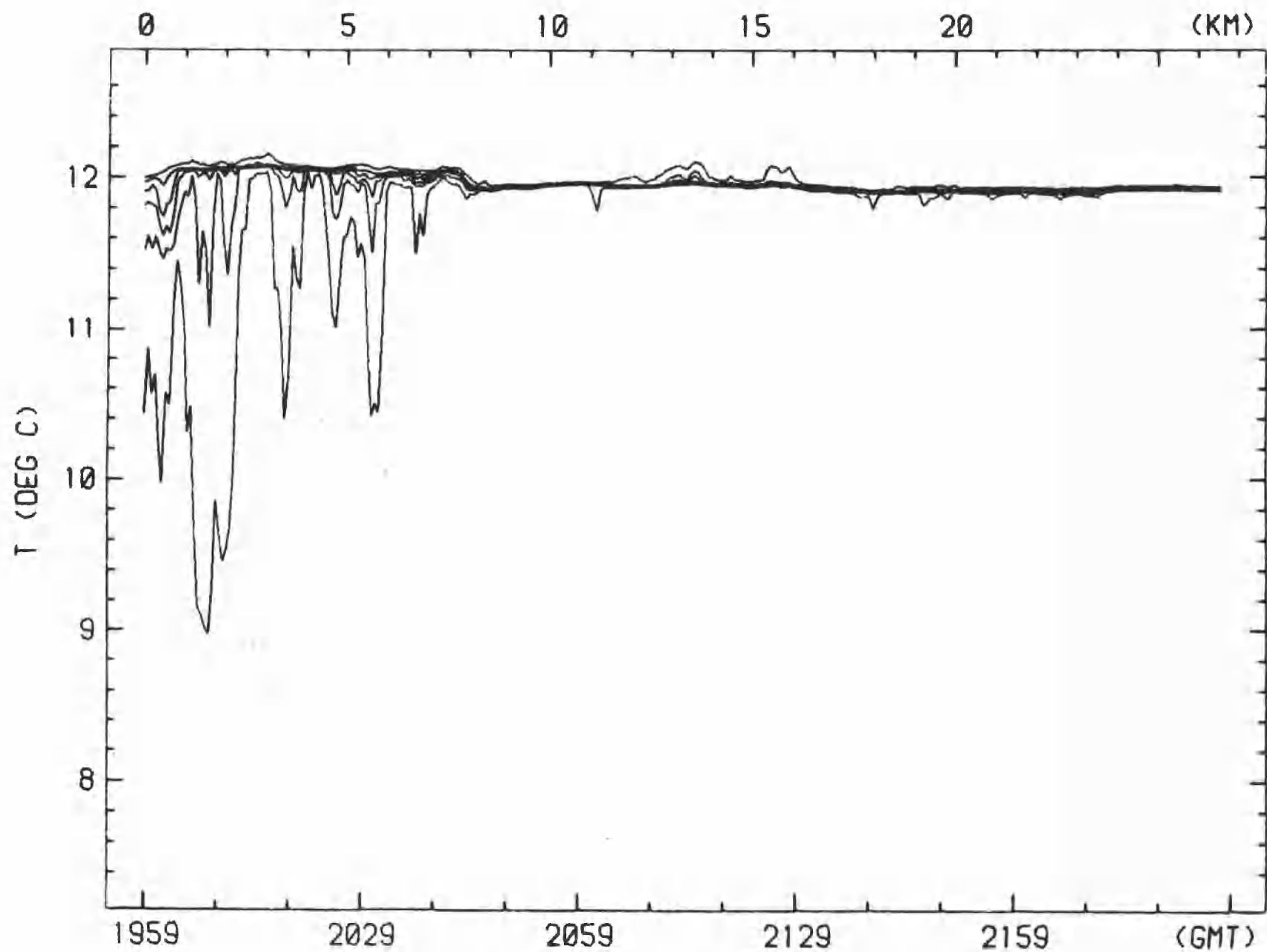
RUN 07 26 AUG 77 TEMP VS TIME/DISTANCE
DEPTH = 21.7, 22.7, 24.8, 25.9, 26.9, 28.8, 30.1 m

21.7, 22.7, 24.8, 25.9, 26.9, 28.0, 30.1 M

25

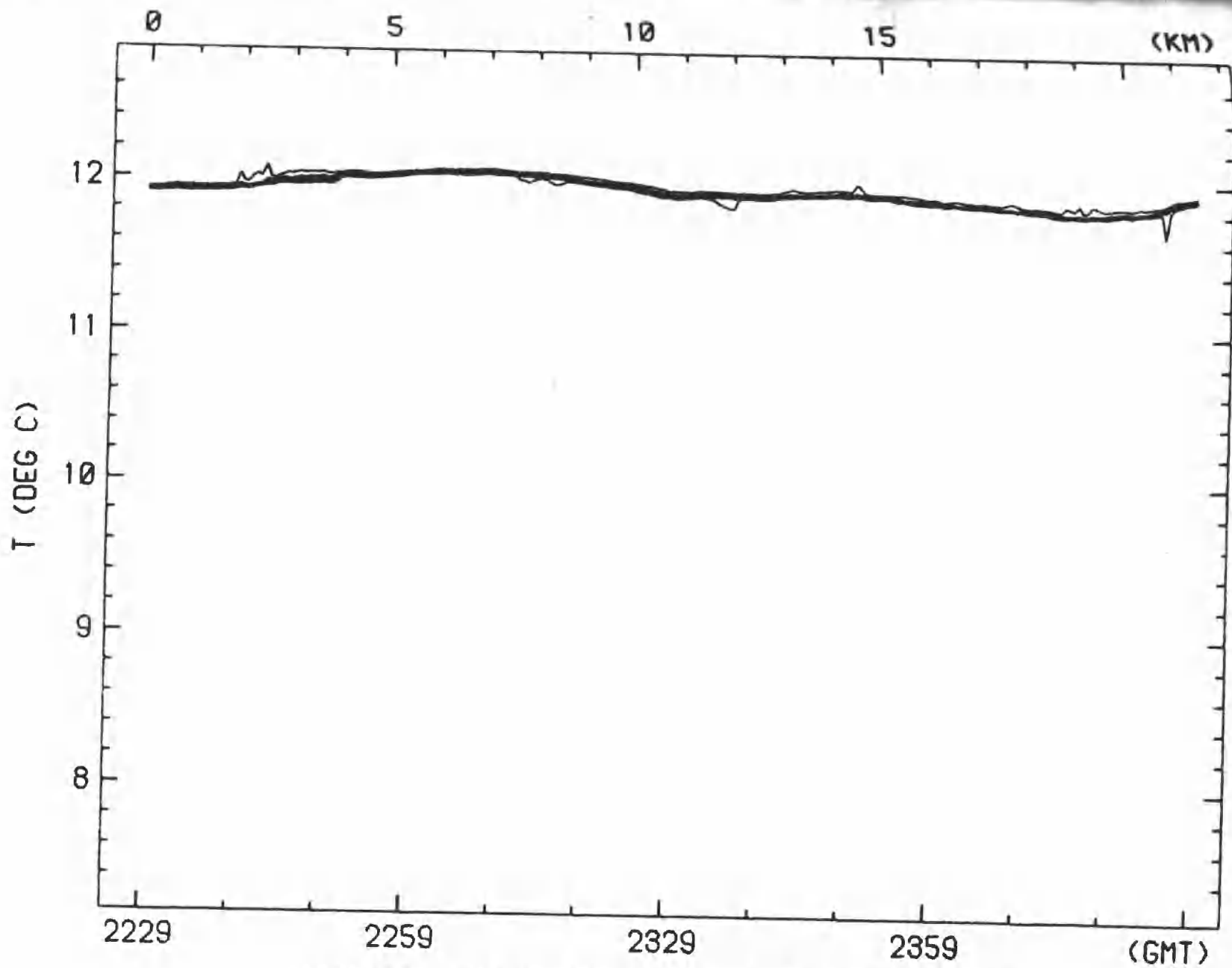


RUN 08 26 AUG 77 TEMP VS TIME/DISTANCE
DEPTH = 21.7, 22.7, 24.8, 25.9, 26.9, 28.0, 30.1 M

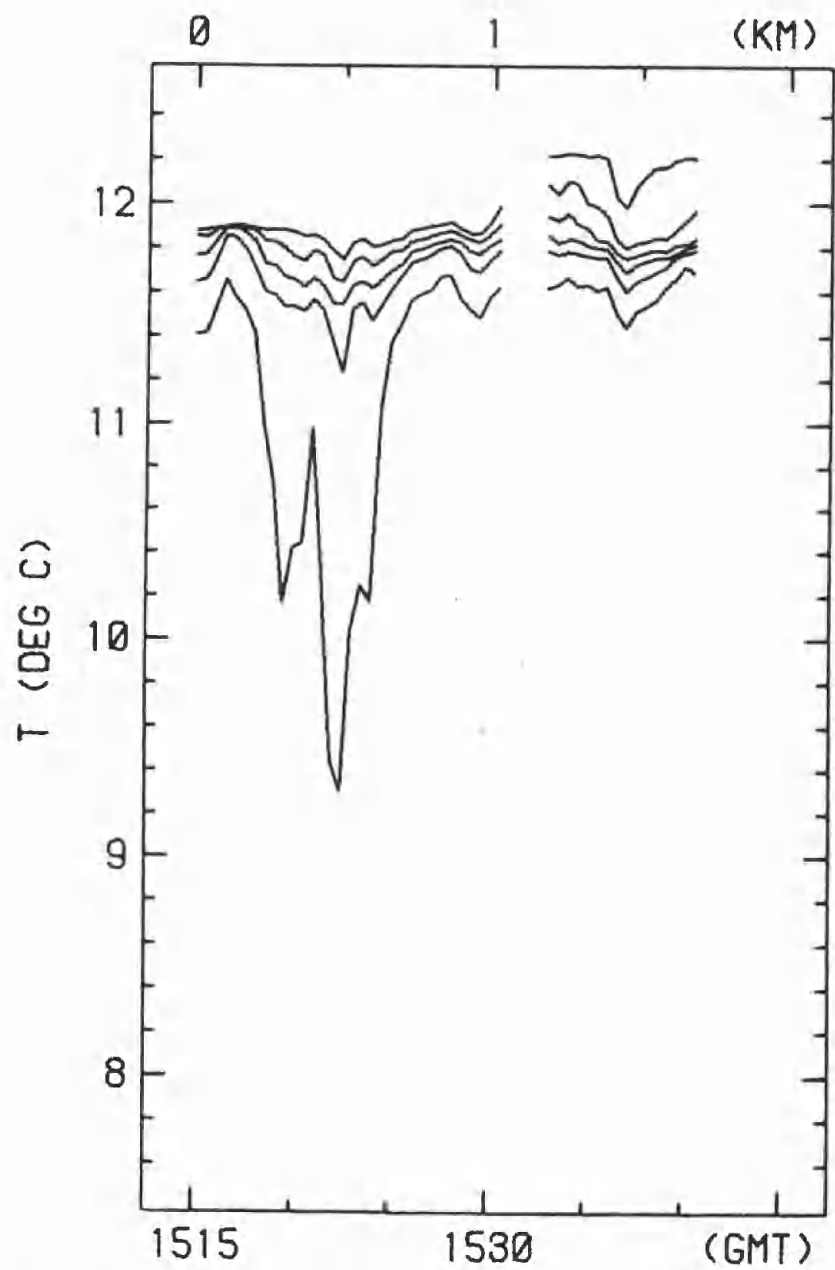


RUN 09 26 AUG 77 TEMP VS TIME/DISTANCE

DEPTH = 22 7.24 8.25 9.26 9.28 0.92 1.11

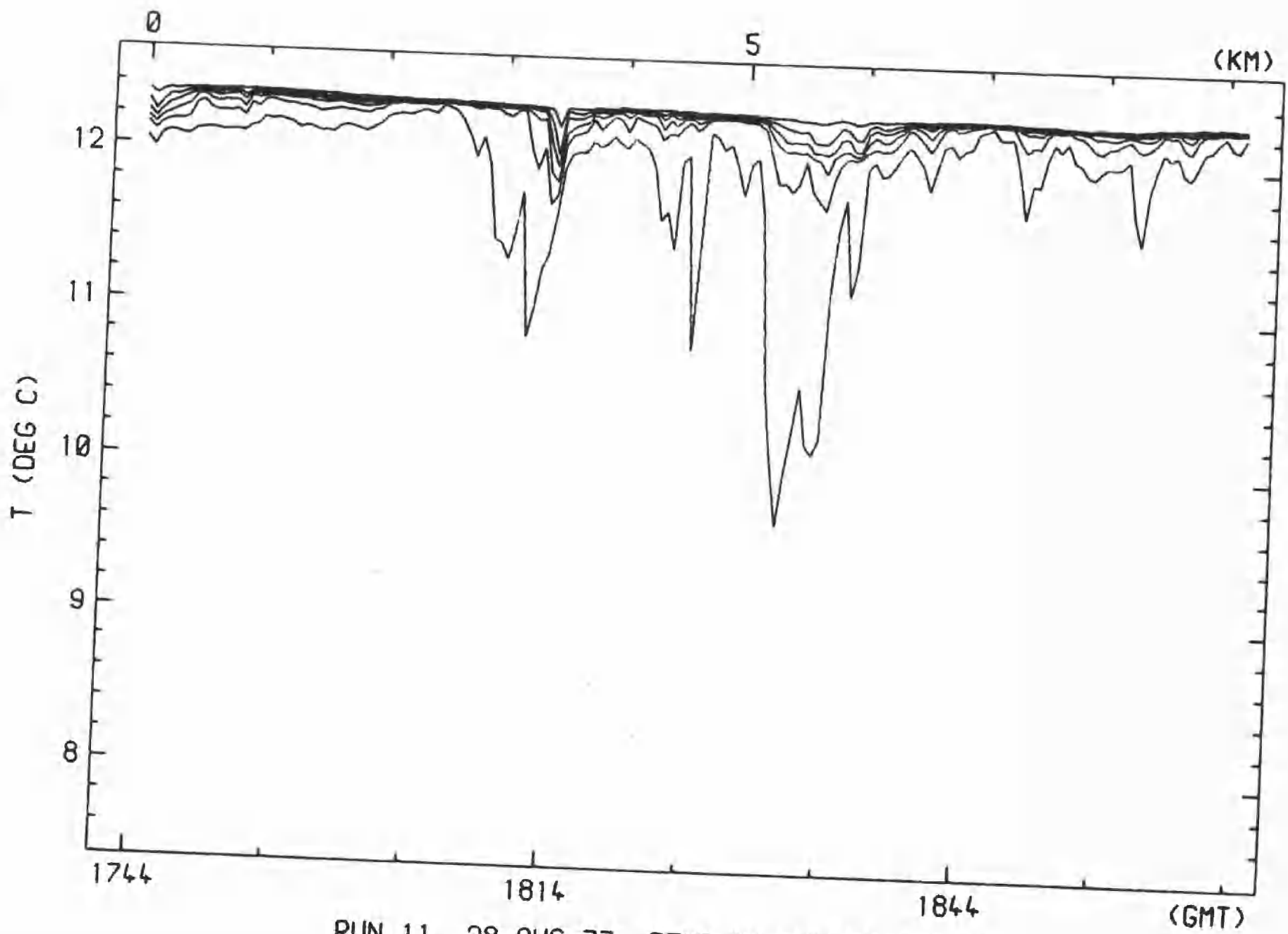


RUN 09 26 AUG 77 TEMP VS TIME/DISTANCE
DEPTH = 22.7, 24.8, 25.9, 26.9, 28.0, 30.1 M



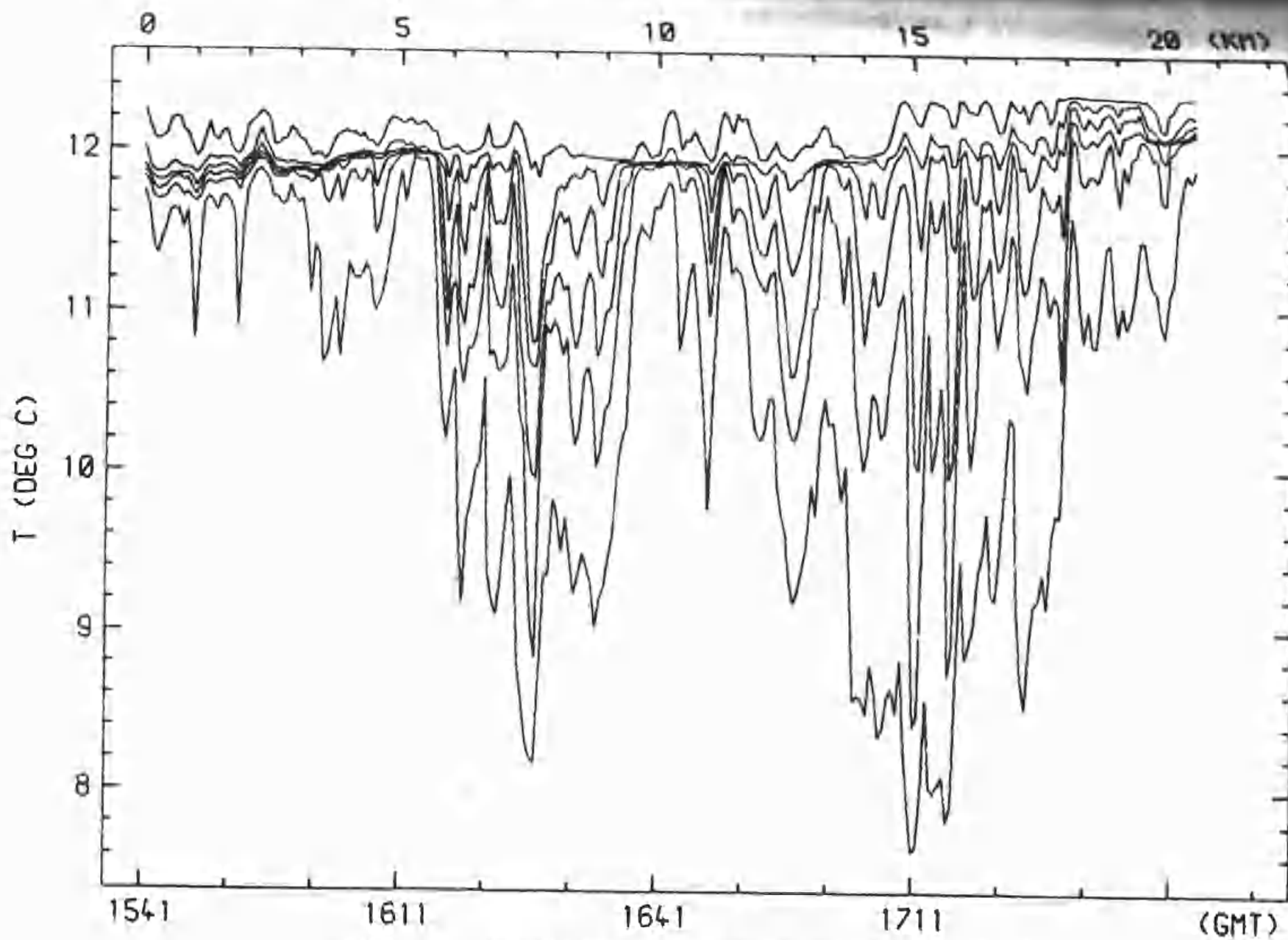
RUNS 10-11 28 AUG 77 TEMP VS TIME/DISTANCE

DEPTH = 22.7, 24.8, 25.9, 26.9, 28.0, 30.1 M

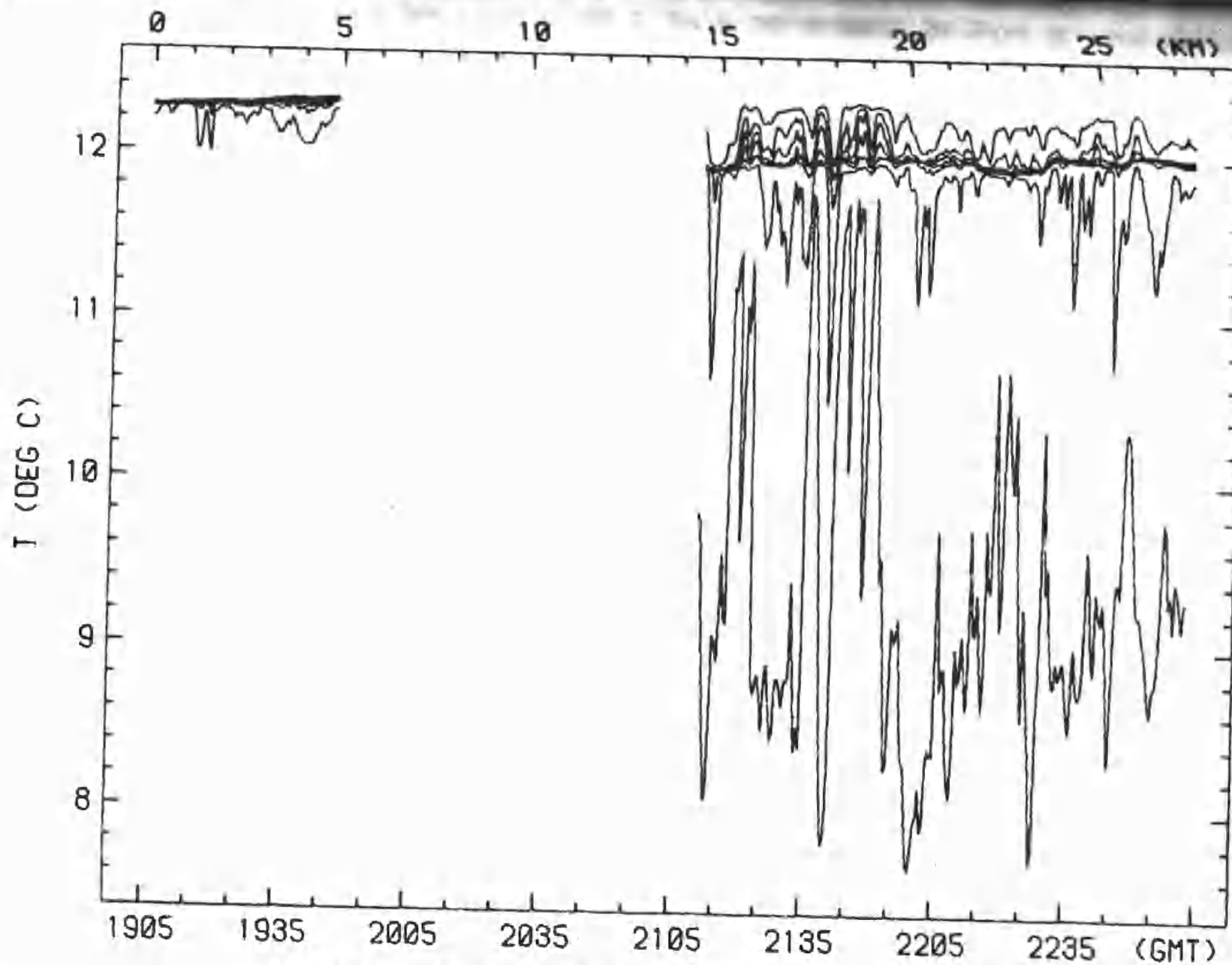


RUN 11 28 AUG 77 TEMP VS TIME/DISTANCE

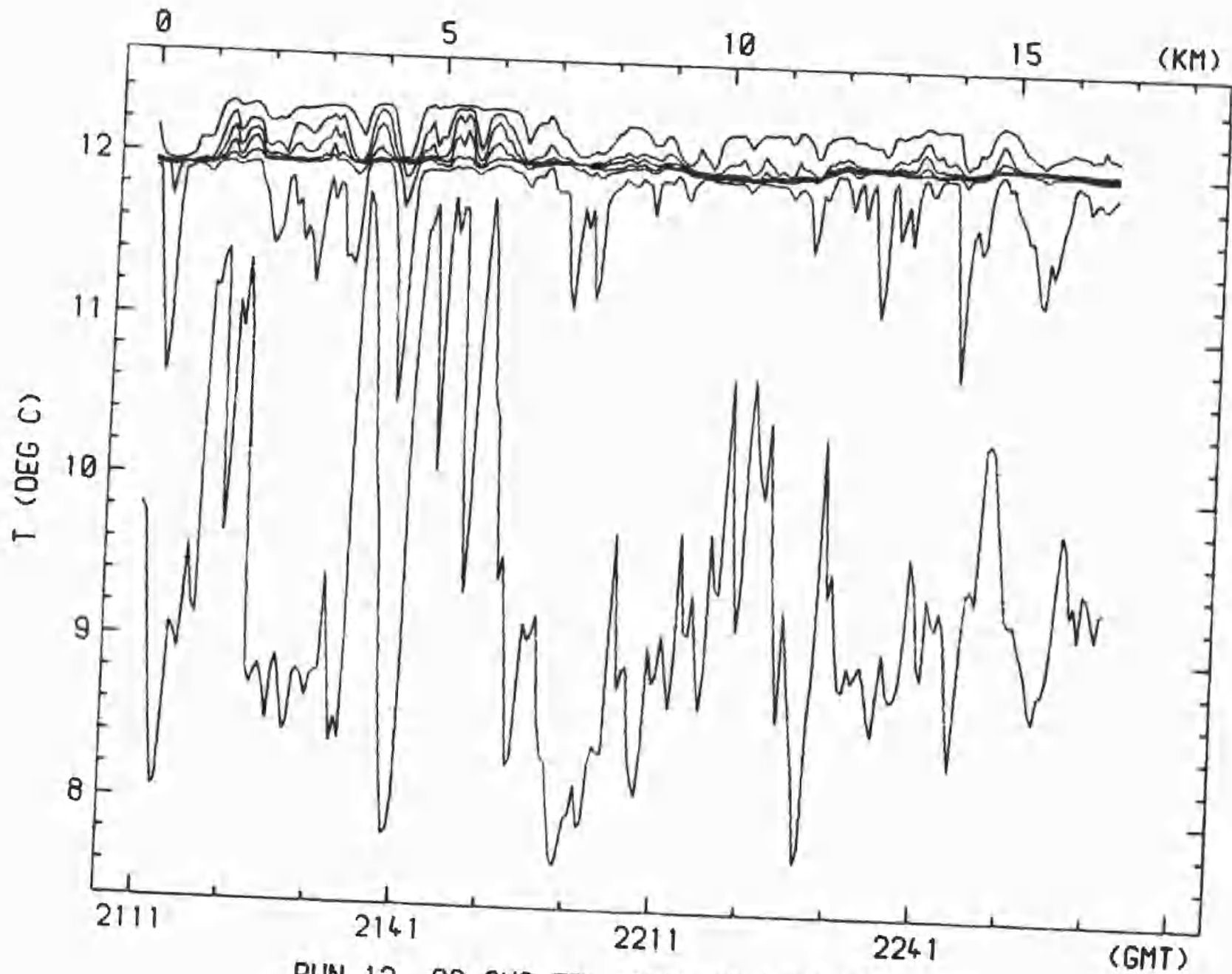
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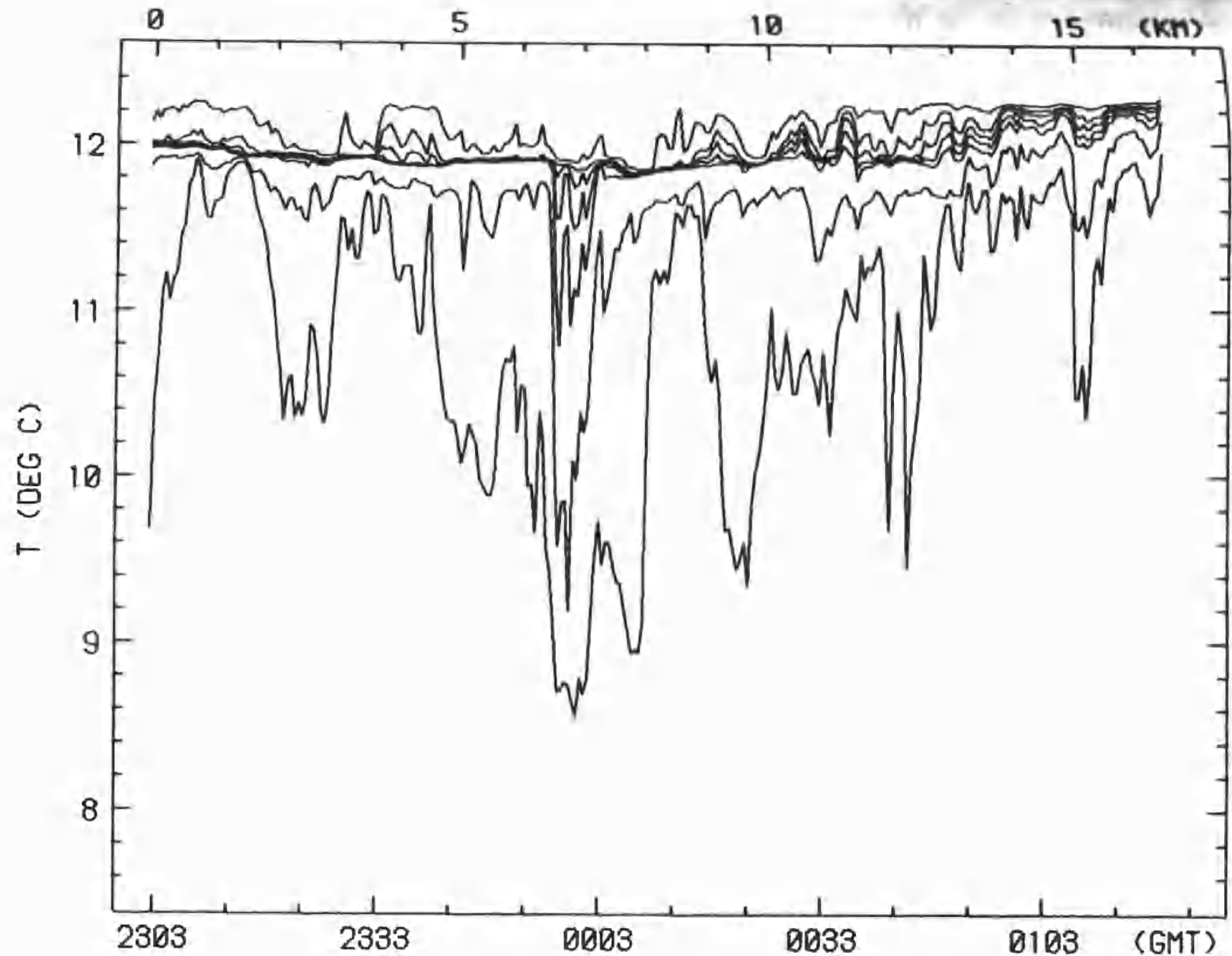
RUN 11 28 AUG 77 TEMP VS TIME/DISTANCE
DEPTH = 22.7, 24.8, 25.9, 26.9, 28.0, 30.1 M



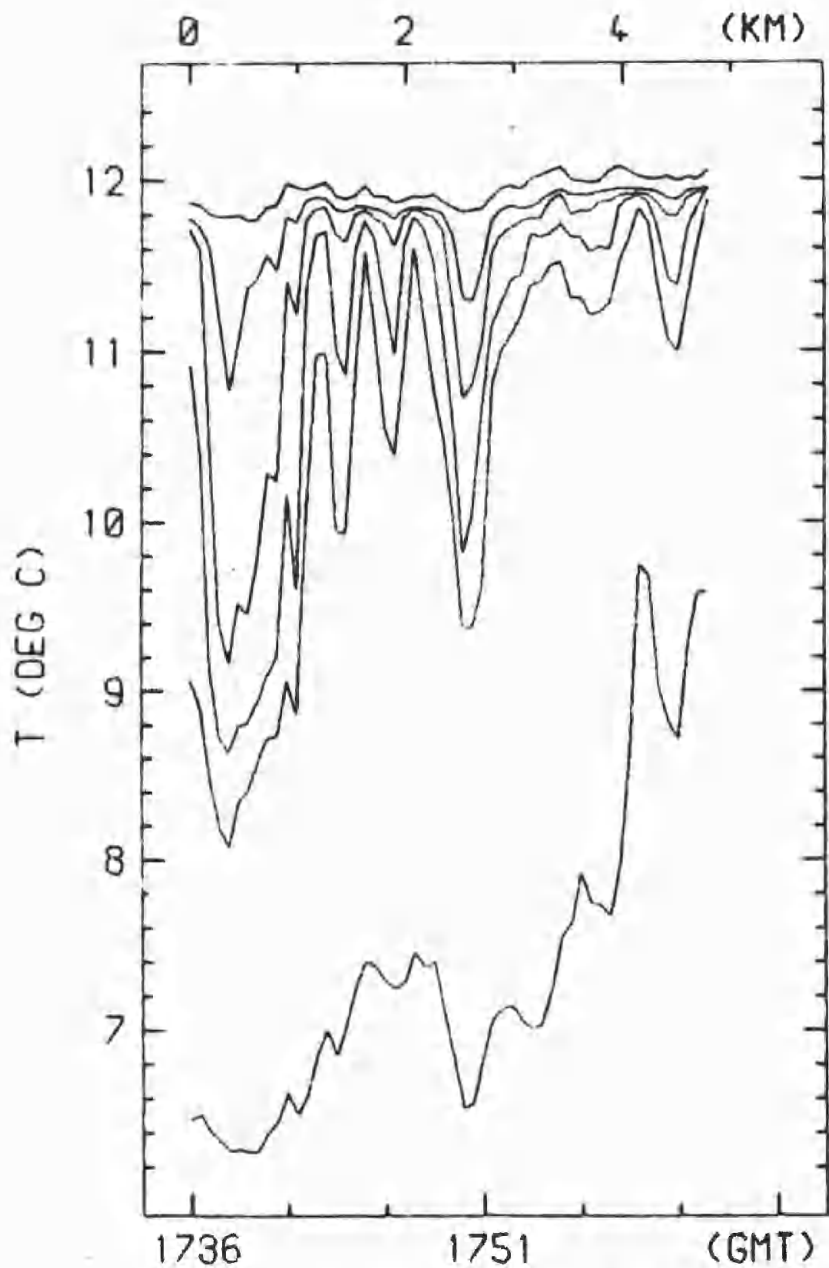
RUNS 11-12 28 AUG 77 TEMP VS TIME/DISTANCE
 DEPTH = 22.7, 24.8, 25.9, 26.9, 28.0, 30.1, 34.3 M



RUN 12 28 AUG 77 TEMP VS TIME/DISTANCE
 DEPTH = 22.7, 24.8, 25.9, 26.9, 28.0, 30.1, 34.3, 41.1

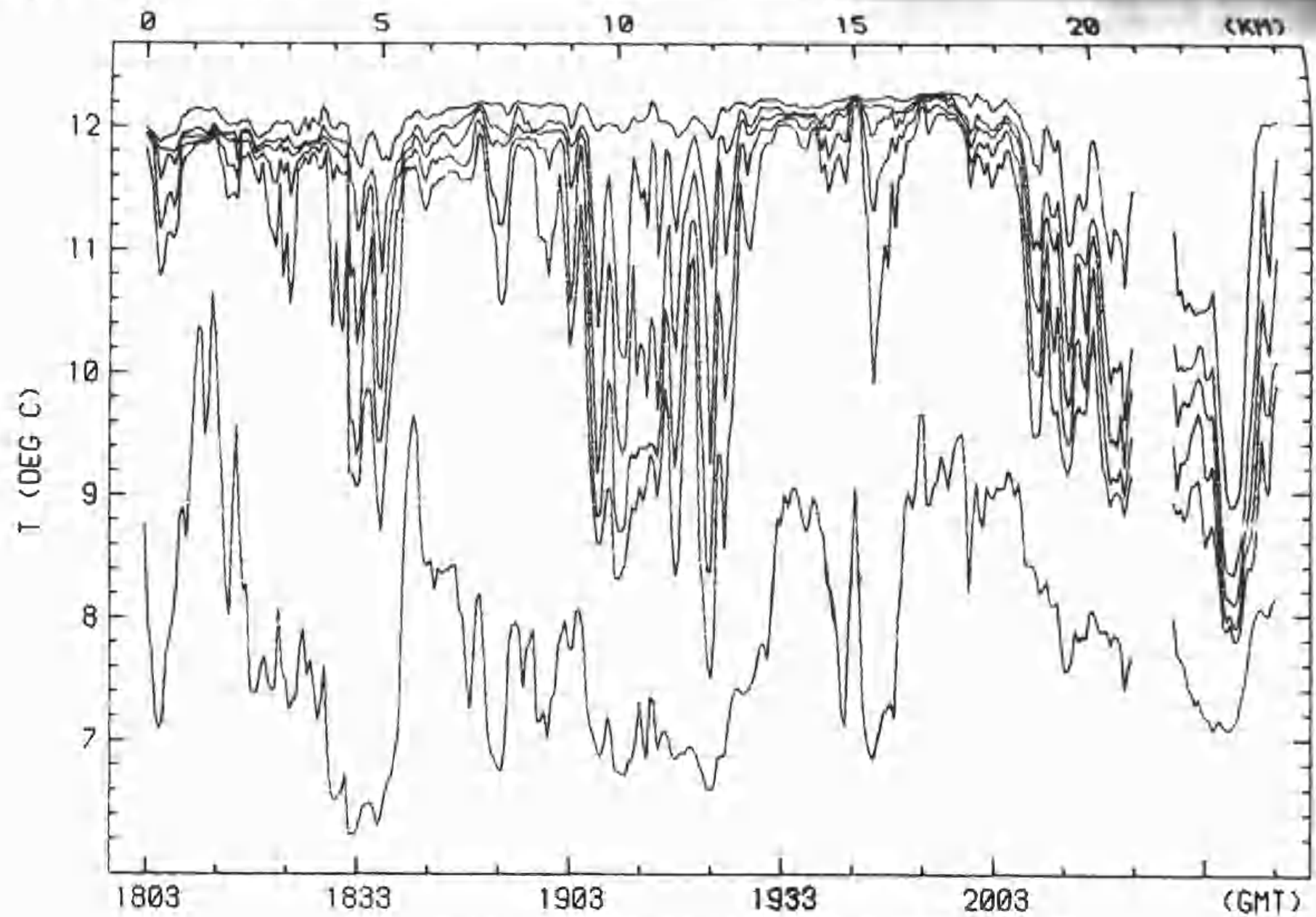


RUN 12 28 AUG 77 TEMP VS TIME/DISTANCE
DEPTH = 22.7, 24.8, 25.9, 26.9, 28.0, 30.1, 34.3 M

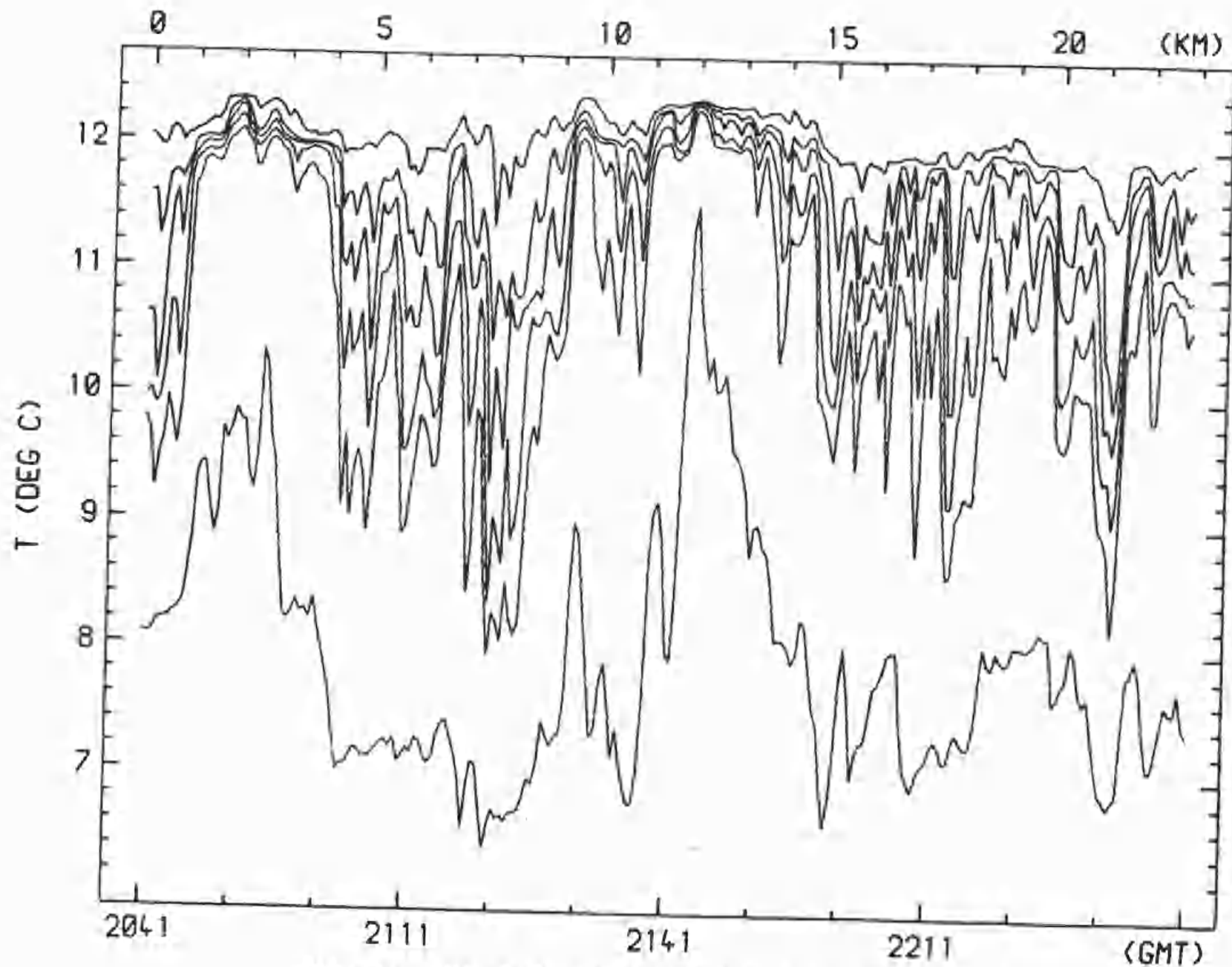


RUN 13 30 AUG 77 TEMP VS TIME/DISTANCE
 DEPTH = 28.5, 30.6, 31.7, 32.7, 33.8, 40.0 M

35

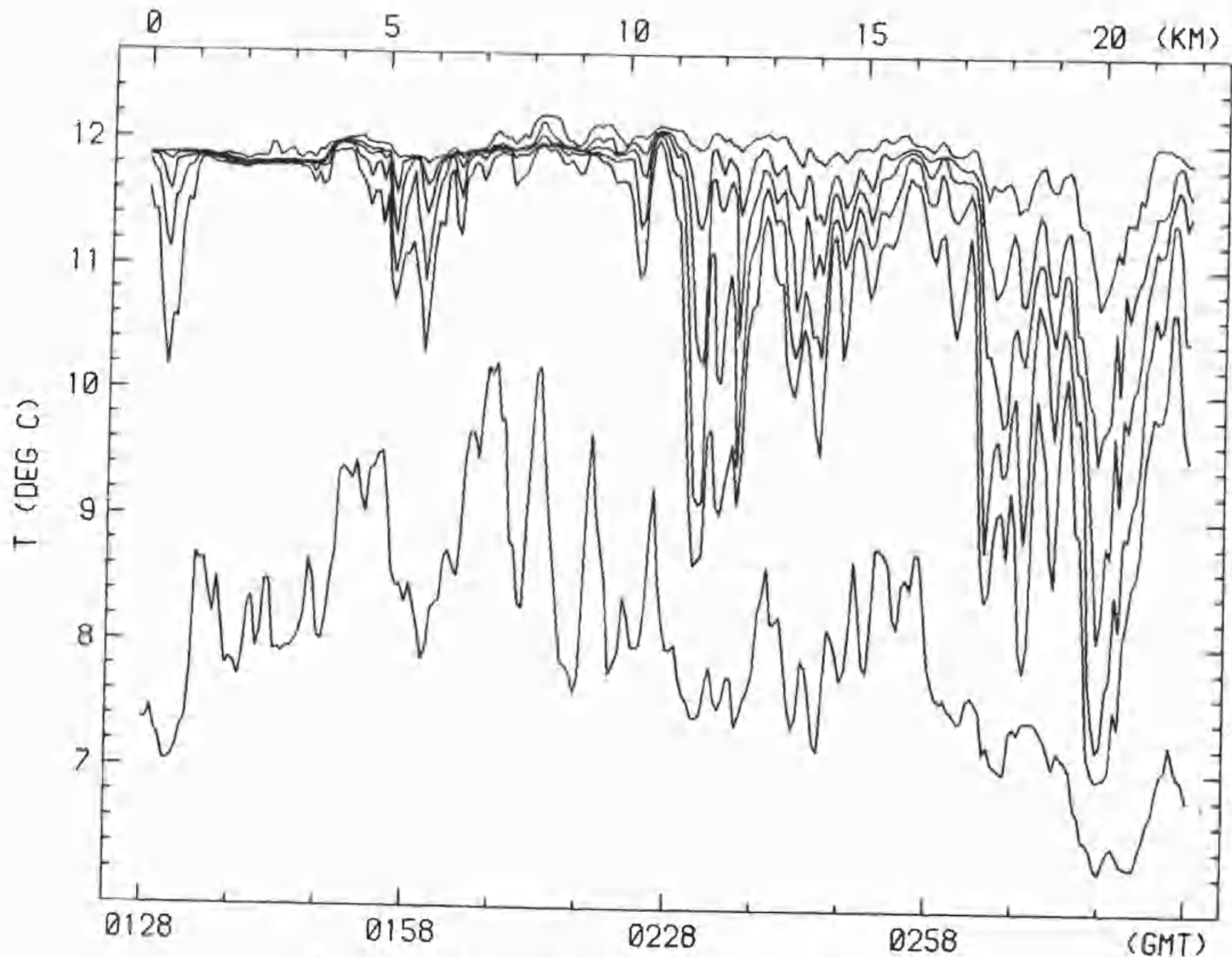


RUNS 13-14 30 AUG 77 TEMP VS TIME/DISTANCE
DEPTH = 28.5, 30.6, 31.7, 32.7, 33.8, 40.0 M



RUN 14 30 AUG 77 TEMP VS TIME/DISTANCE

DEPTH = 28.5, 30.6, 31.7, 32.7, 33.8, 34.9, 36.0, 37.1, 38.2, 39.3

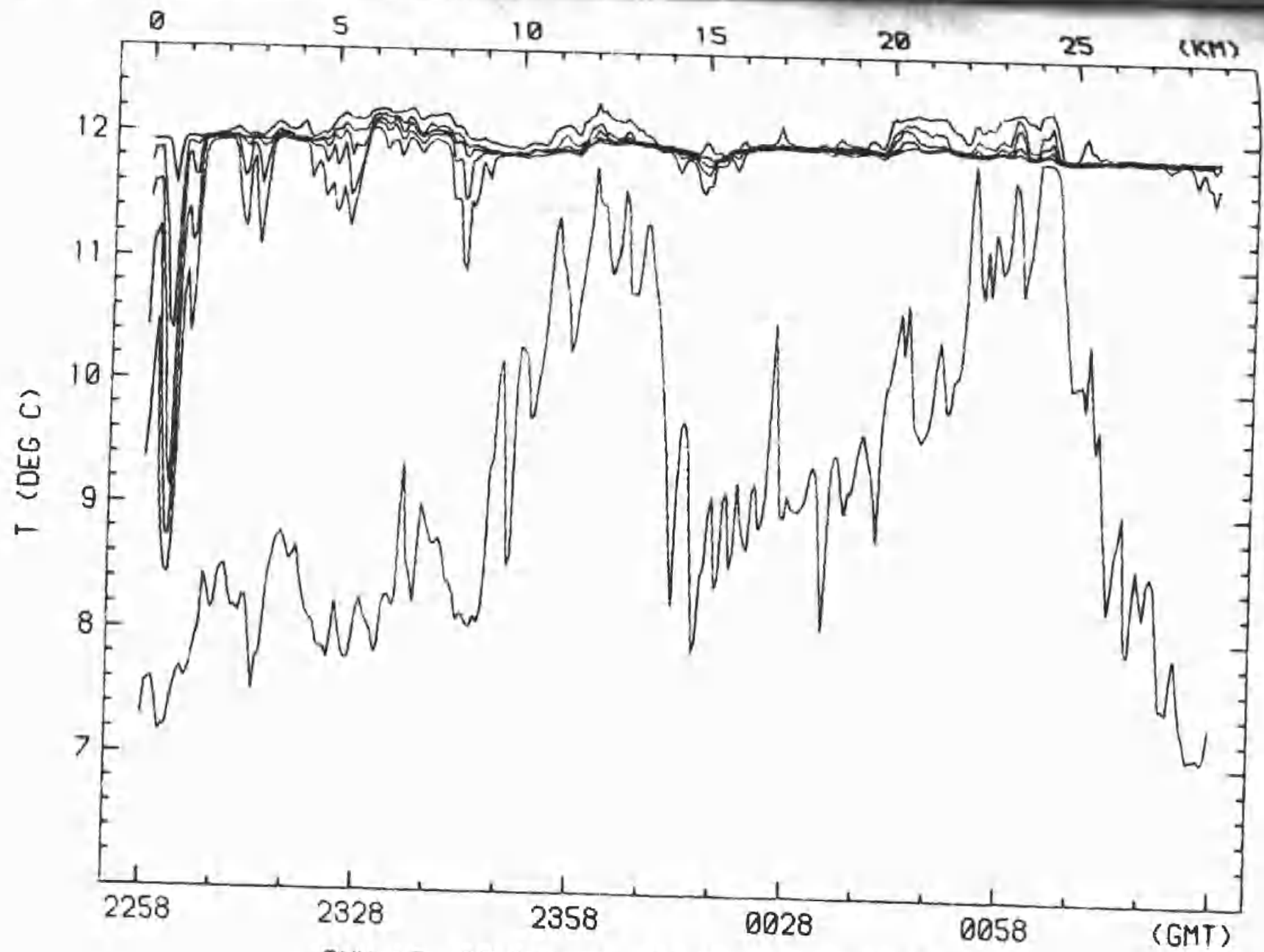


RUN 15 31 AUG 77 TEMP VS TIME/DISTANCE

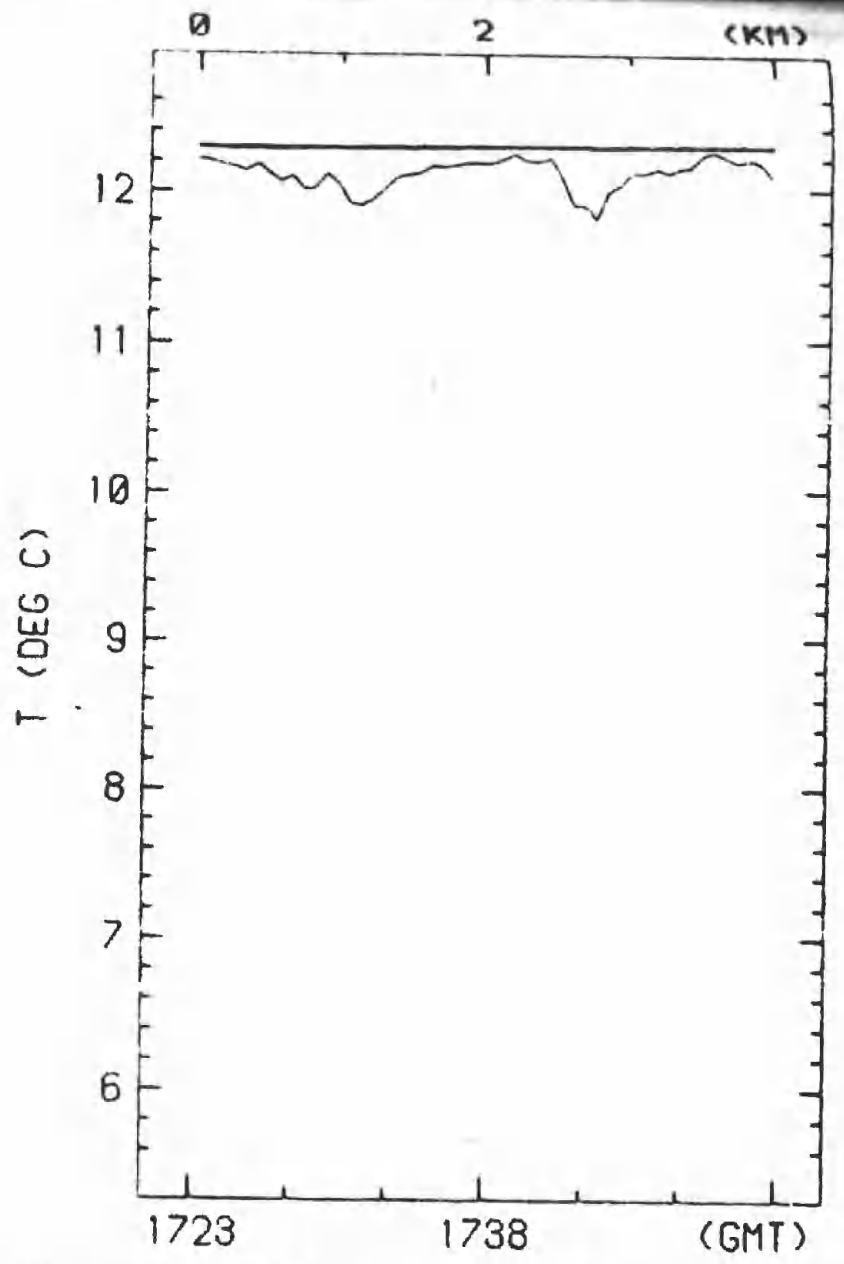
DEPTH = 28.5, 30.6, 31.7, 32.7, 33.8, 40.0 M

DEPTH = 28.5, 30.6, 31.7, 32.7, 33.8, 40.0 M

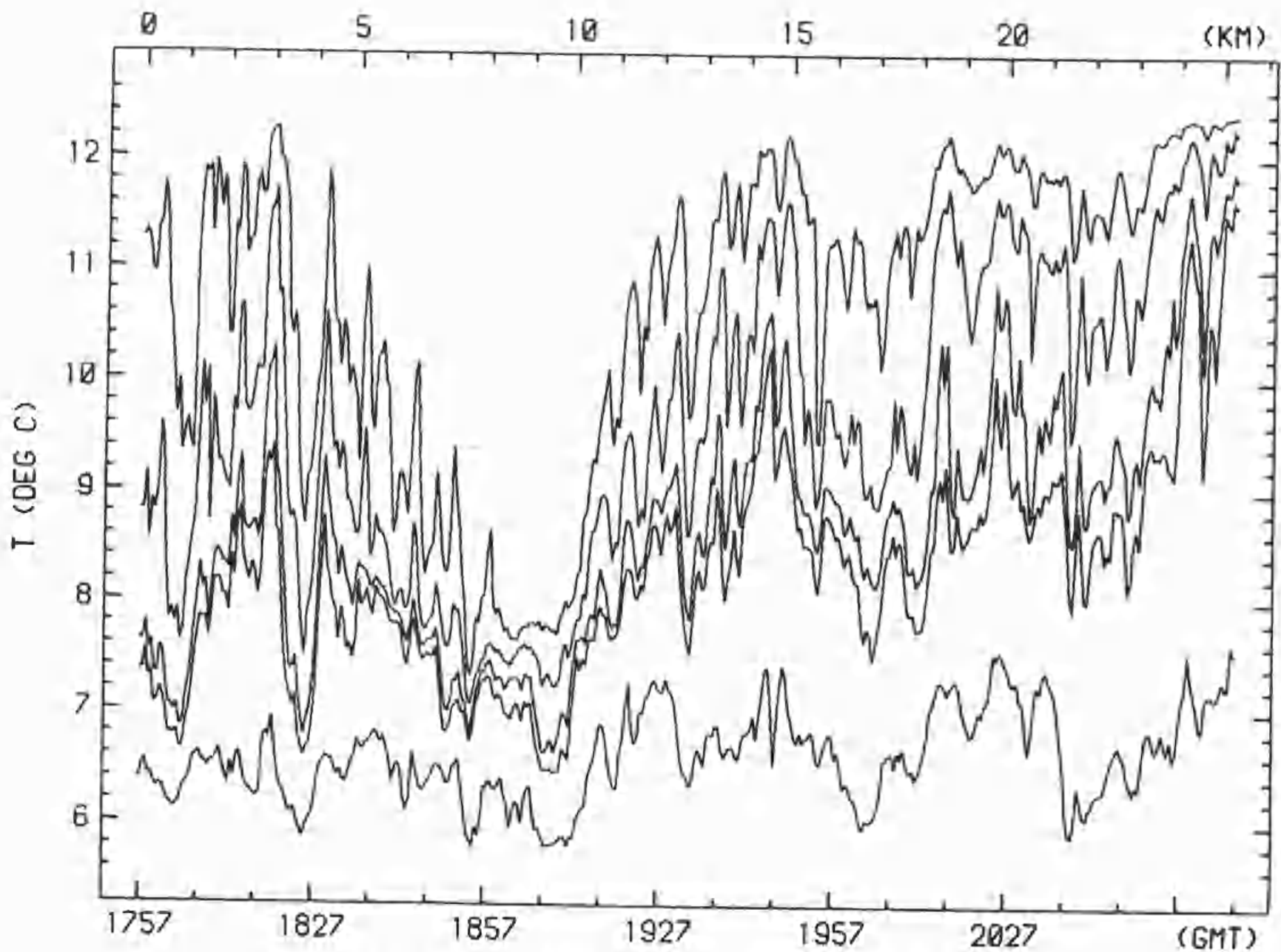
37



RUN 15 30 AUG 77 TEMP VS TIME/DISTANCE
DEPTH = 28.5, 30.6, 31.7, 32.7, 33.8, 40.0 M



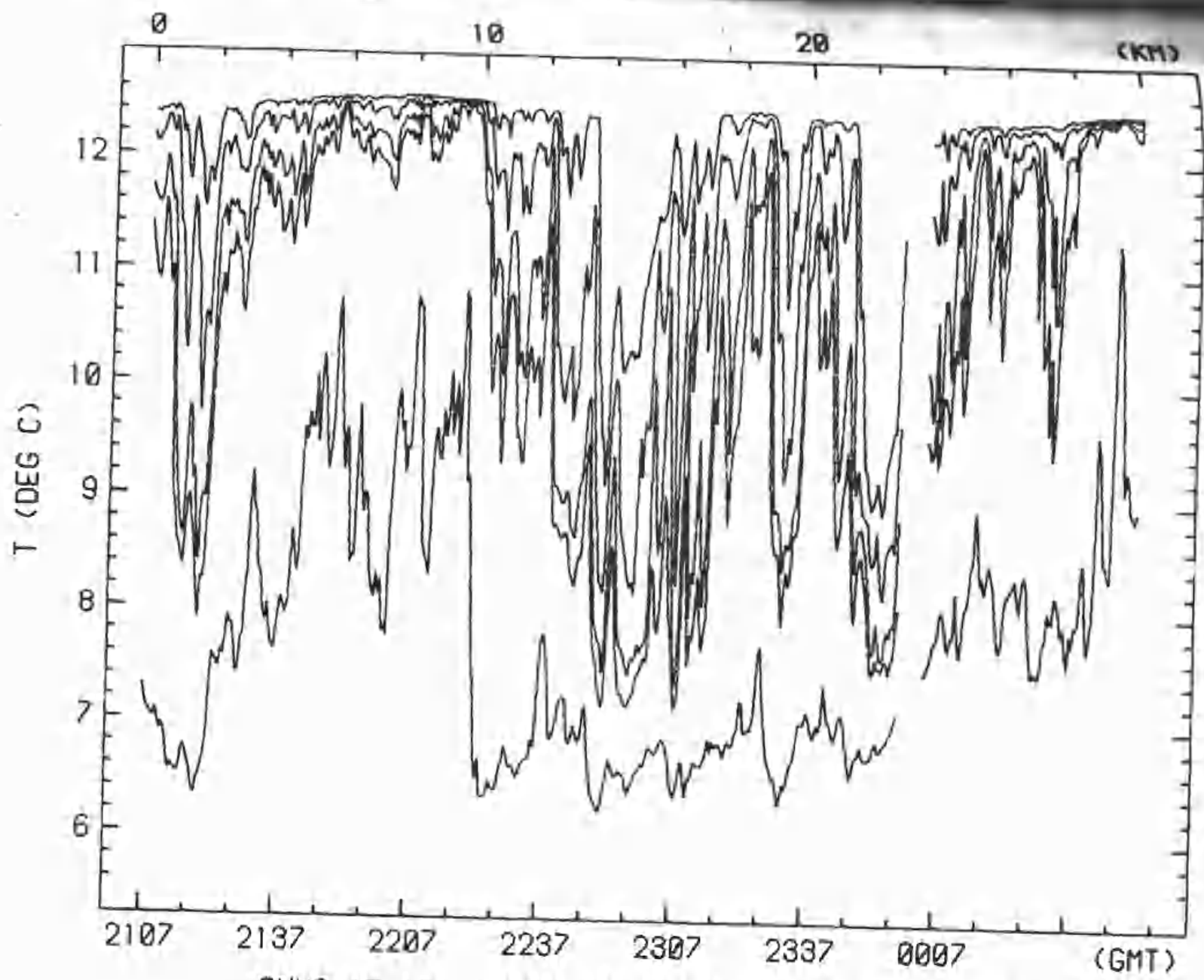
RUN 16 1 SEP 77 TEMP VS TIME/DISTANCE
 DEPTH = 18.6, 20.7, 22.7, 23.8, 30.1 M



RUN 17 1 SEP 77 TEMP VS TIME/DISTANCE

DEPTH = 31.9, 34.0, 36.1, 37.1, 43.4 M

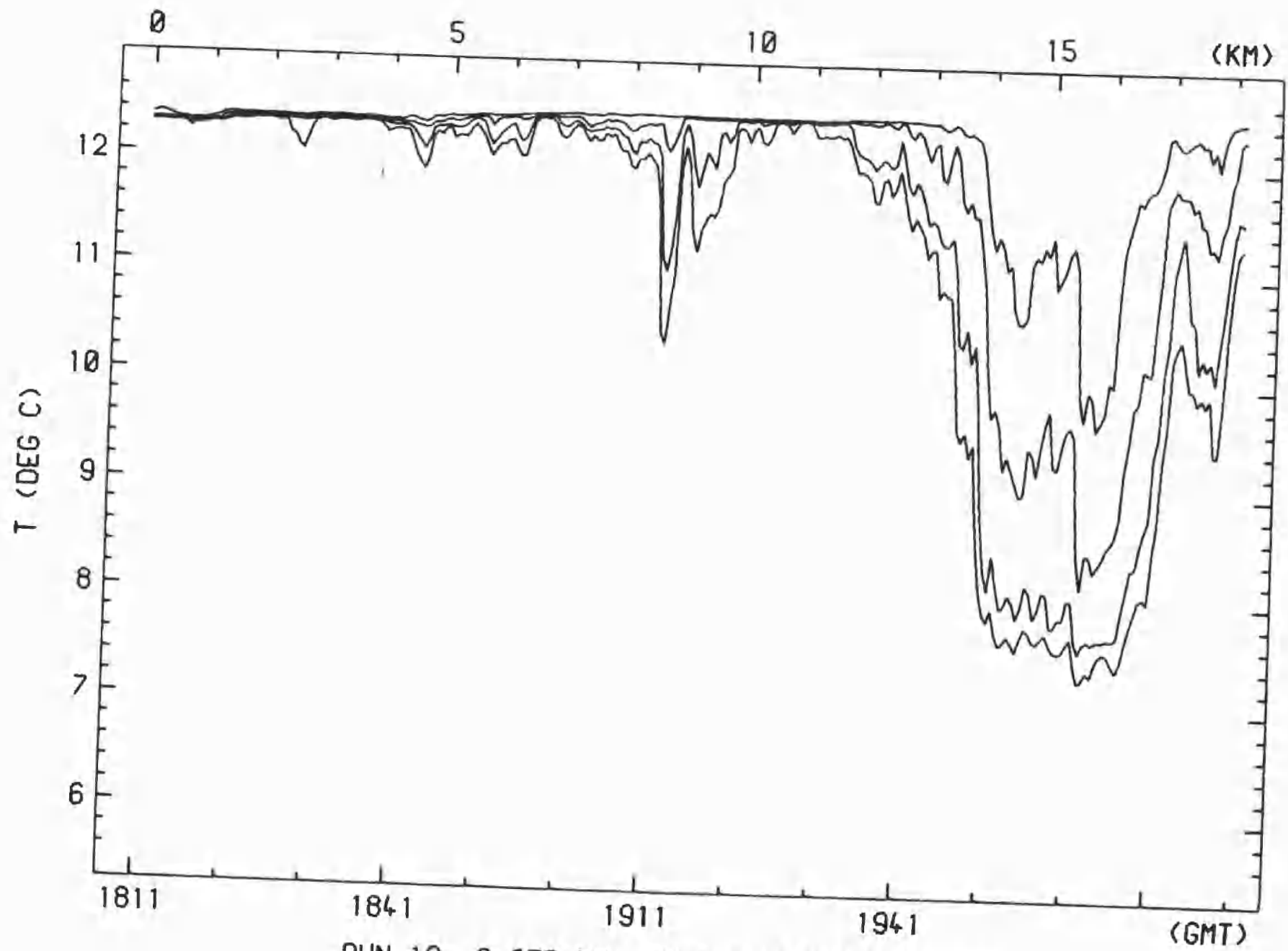
19



RUNS 17-18 1 SEP 77 TEMP VS TIME/DISTANCE

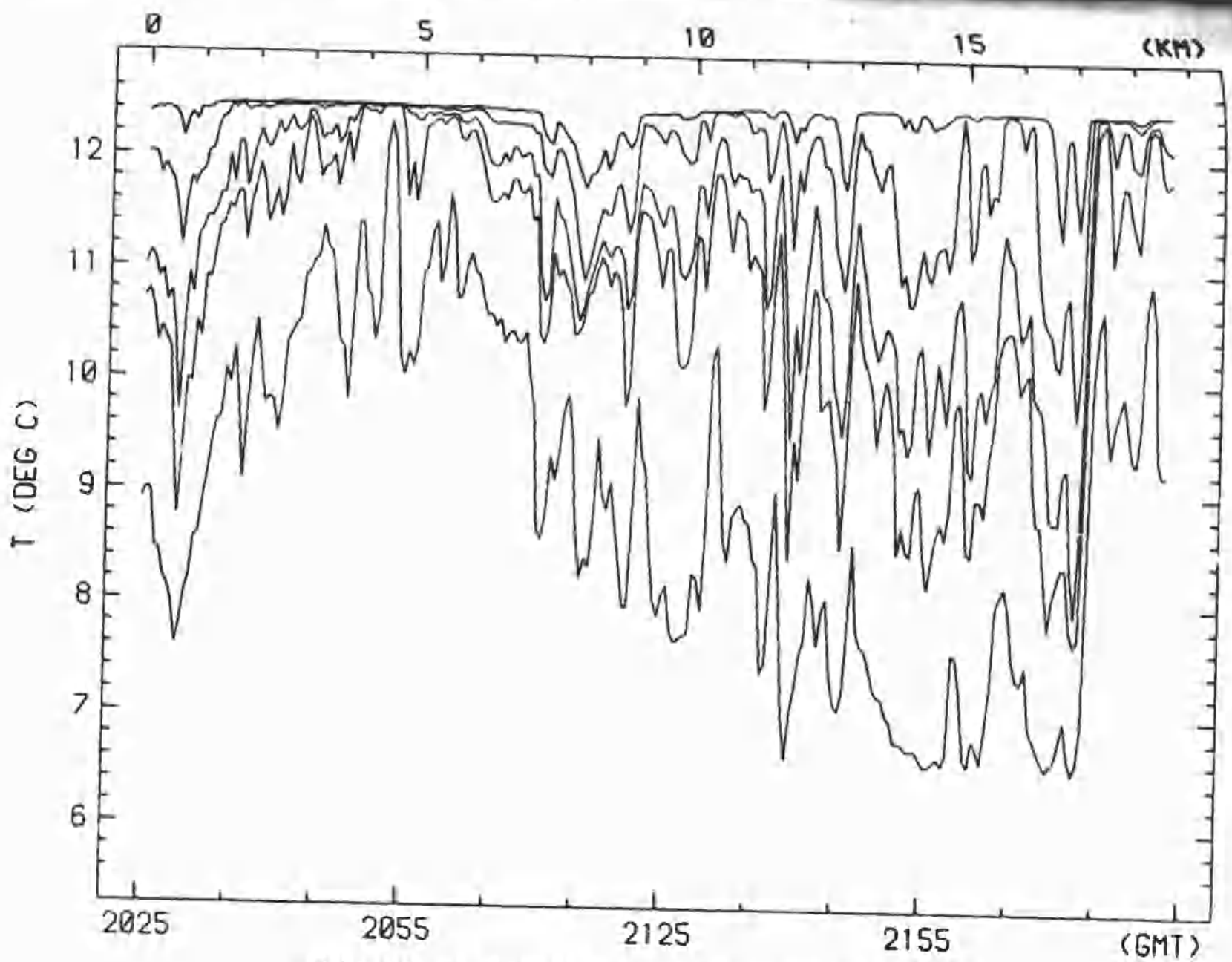
DEPTH = 31.9, 34.0, 36.1, 37.1, 43.4 M

42



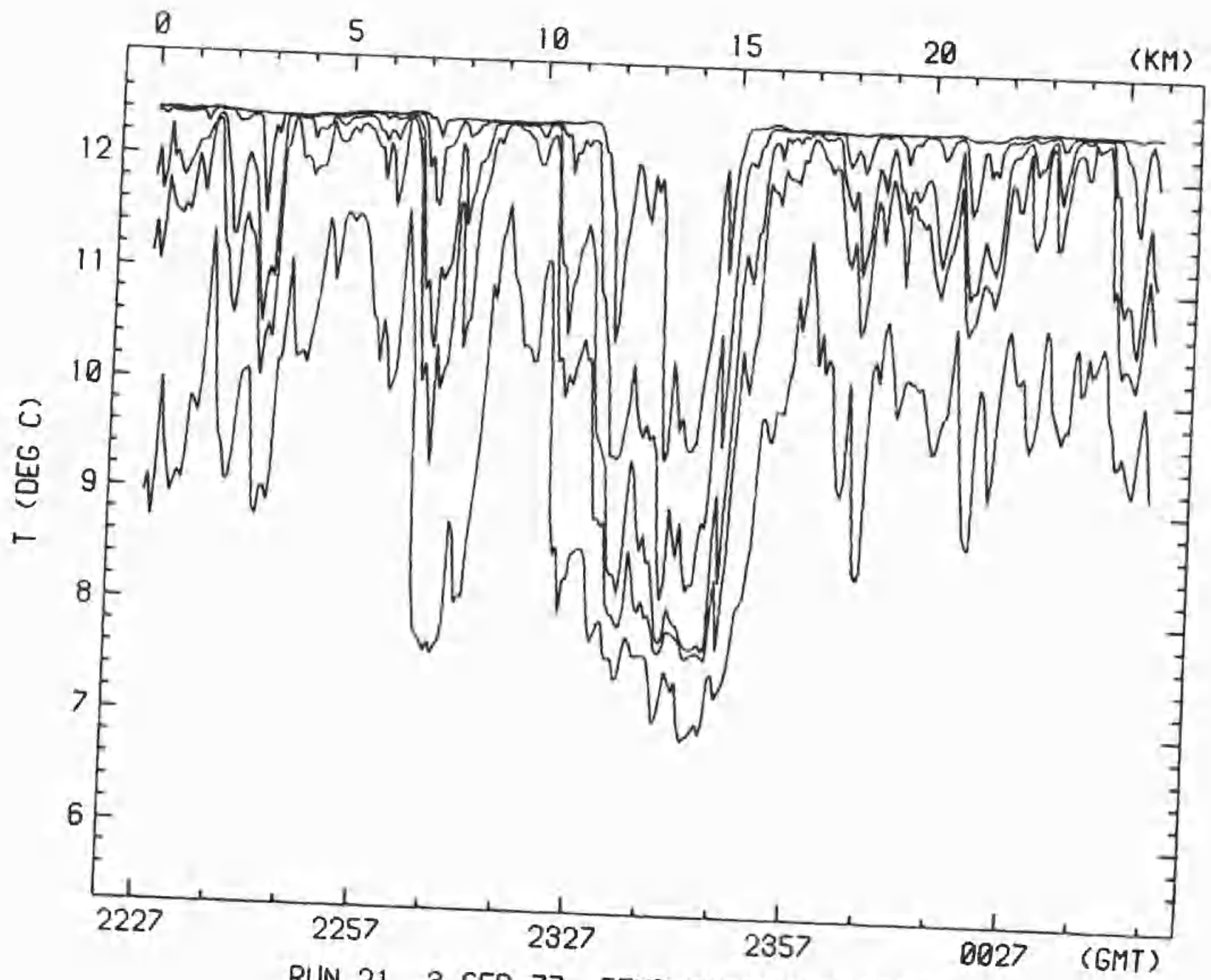
RUN 19 3 SEP 77 TEMP VS TIME/DISTANCE
DEPTH = 29.1.31.2.33.3.34.4 M

43



RUN 20 3 SEP 77 TEMP VS TIME/DISTANCE
 DEPTH = 29.1, 31.2, 33.3, 34.4, 37.5 M

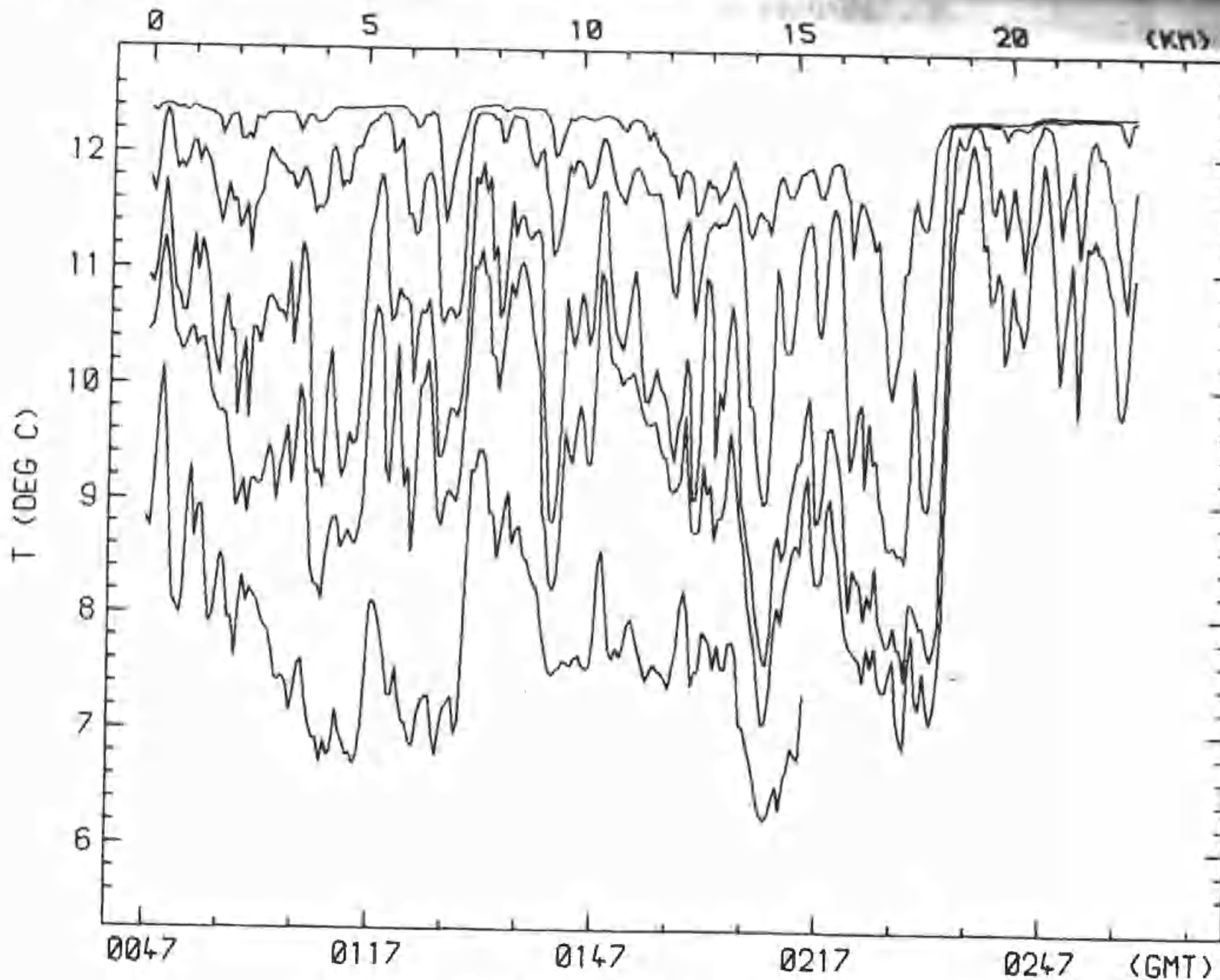
44



RUN 21 3 SEP 77 TEMP VS TIME/DISTANCE

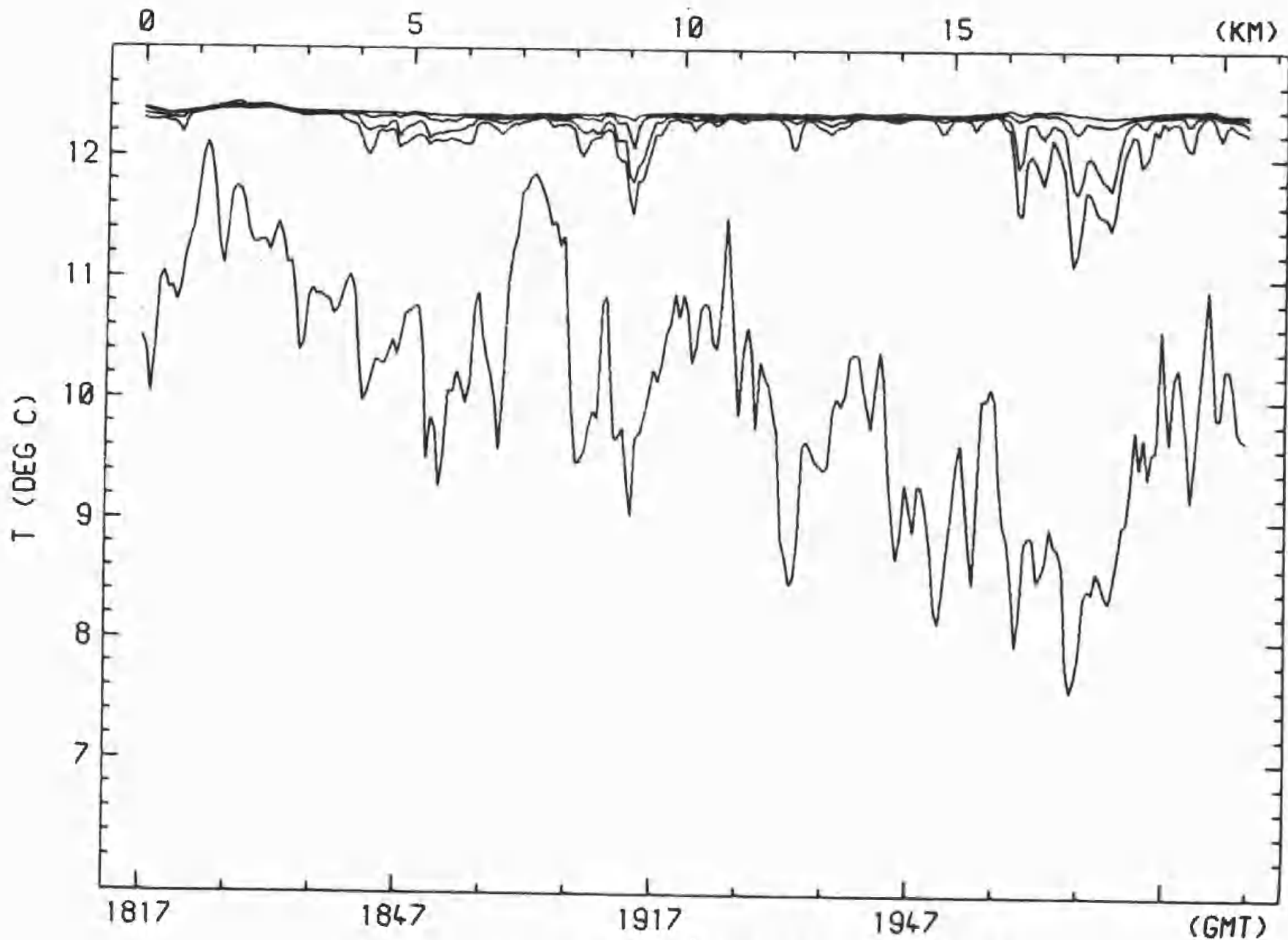
DEPTH = 29 1.31 2.33 3.35 4.37 5.39

DEPTH = 29.1, 31.2, 33.3, 34.4, 37.5 M



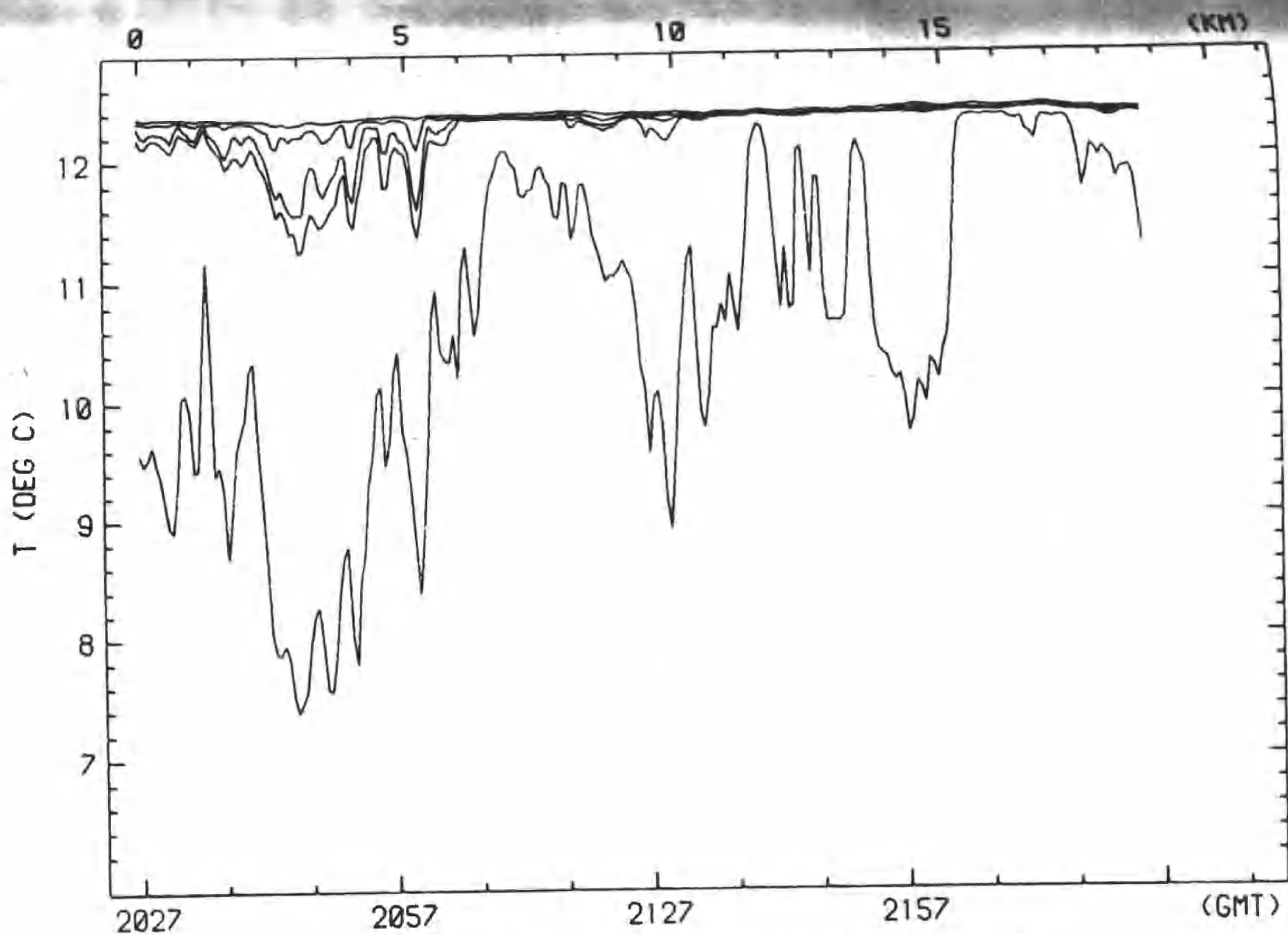
RUN 21 4 SEP 77 TEMP VS TIME/DISTANCE

DEPTH = 29.1, 31.2, 33.3, 34.4, 37.5 M



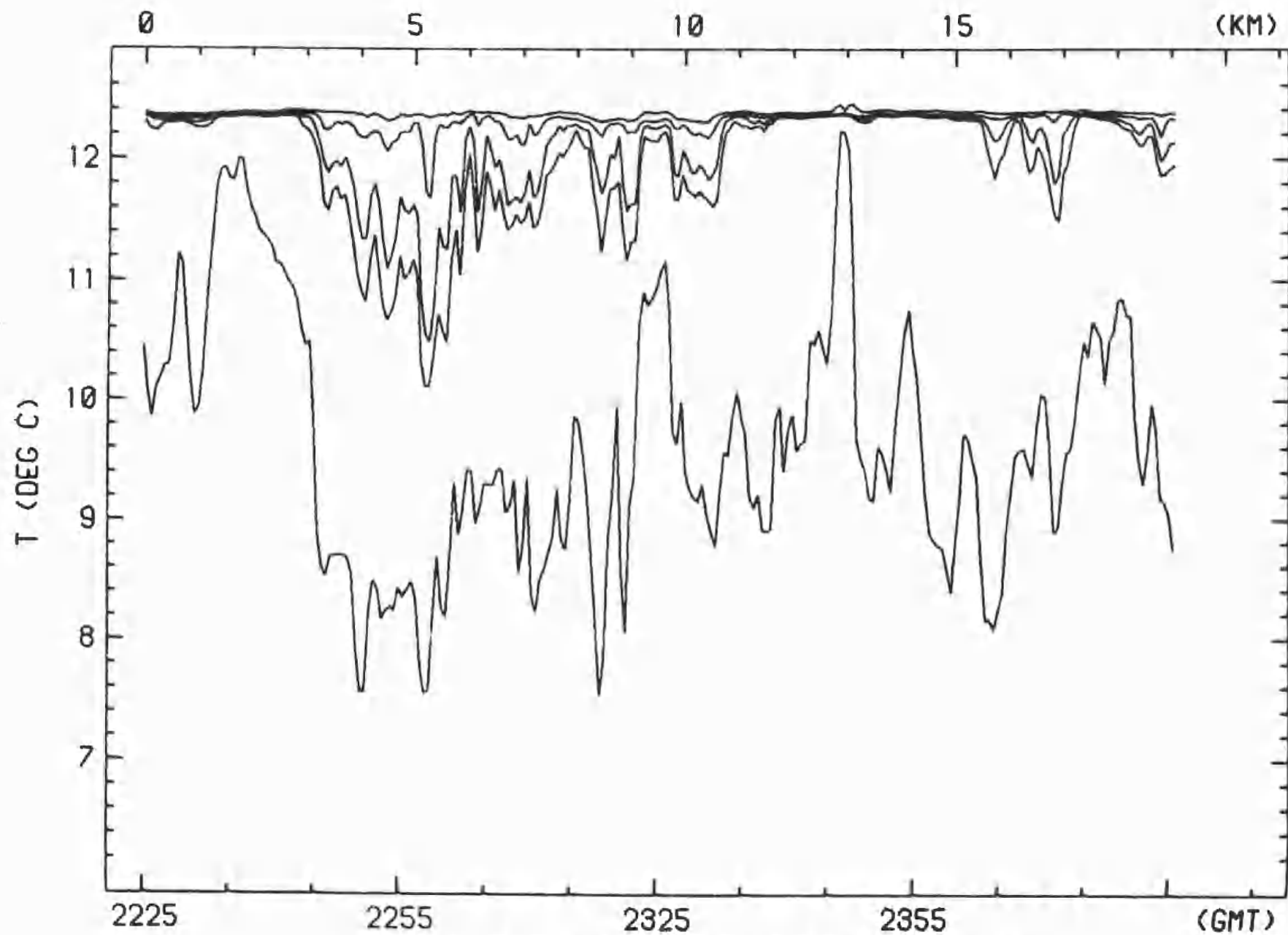
RUN 22 5 SEP 77 TEMP VS TIME/DISTANCE

DEPTH = 28.6, 30.7, 32.8, 33.8, 40.1 M



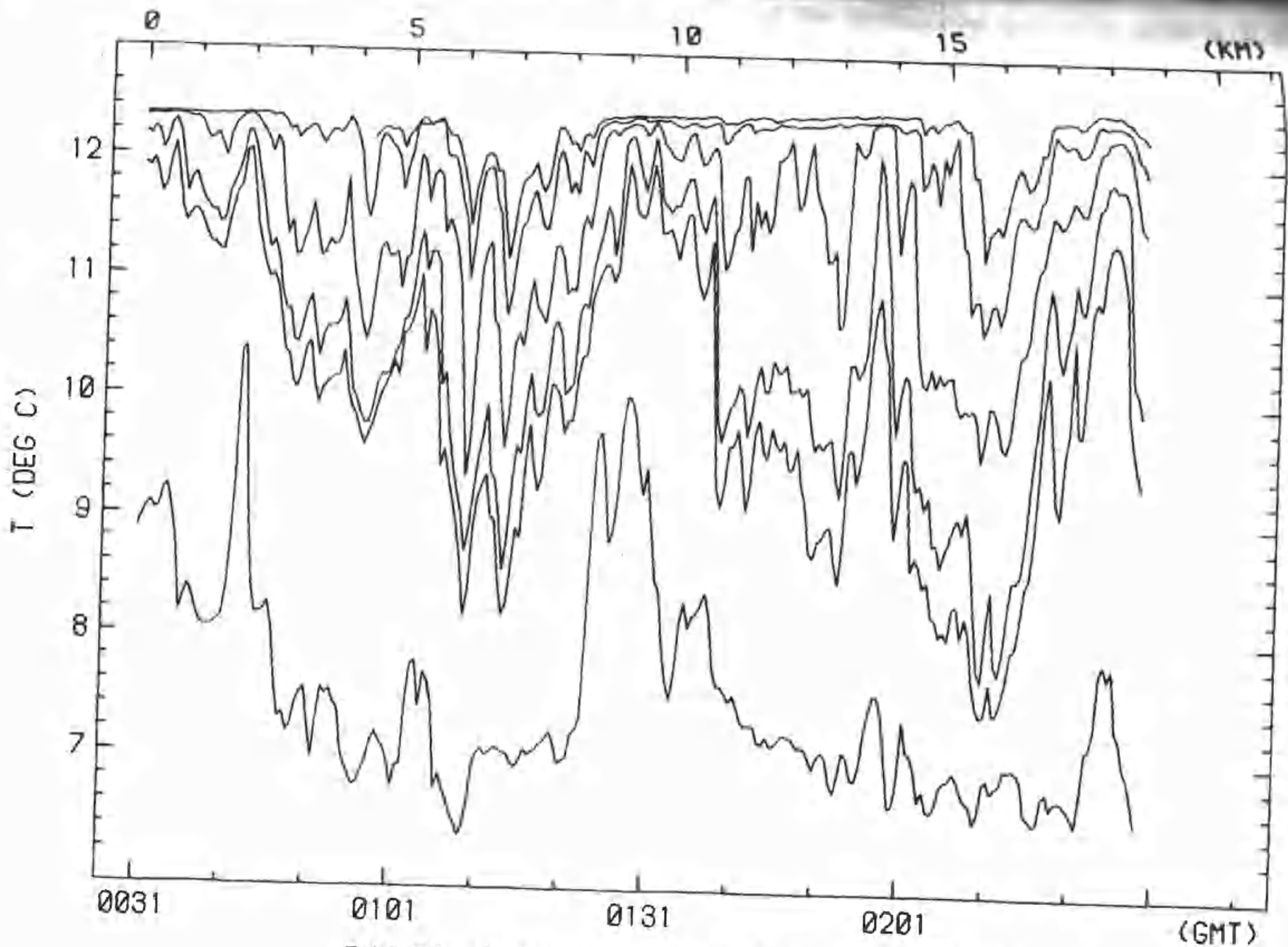
RUN 22 5 SEP 77 TEMP VS TIME/DISTANCE

DEPTH = 28.6, 30.7, 32.8, 33.8, 40.1 M



RUN 22 5 SEP 77 TEMP VS TIME/DISTANCE

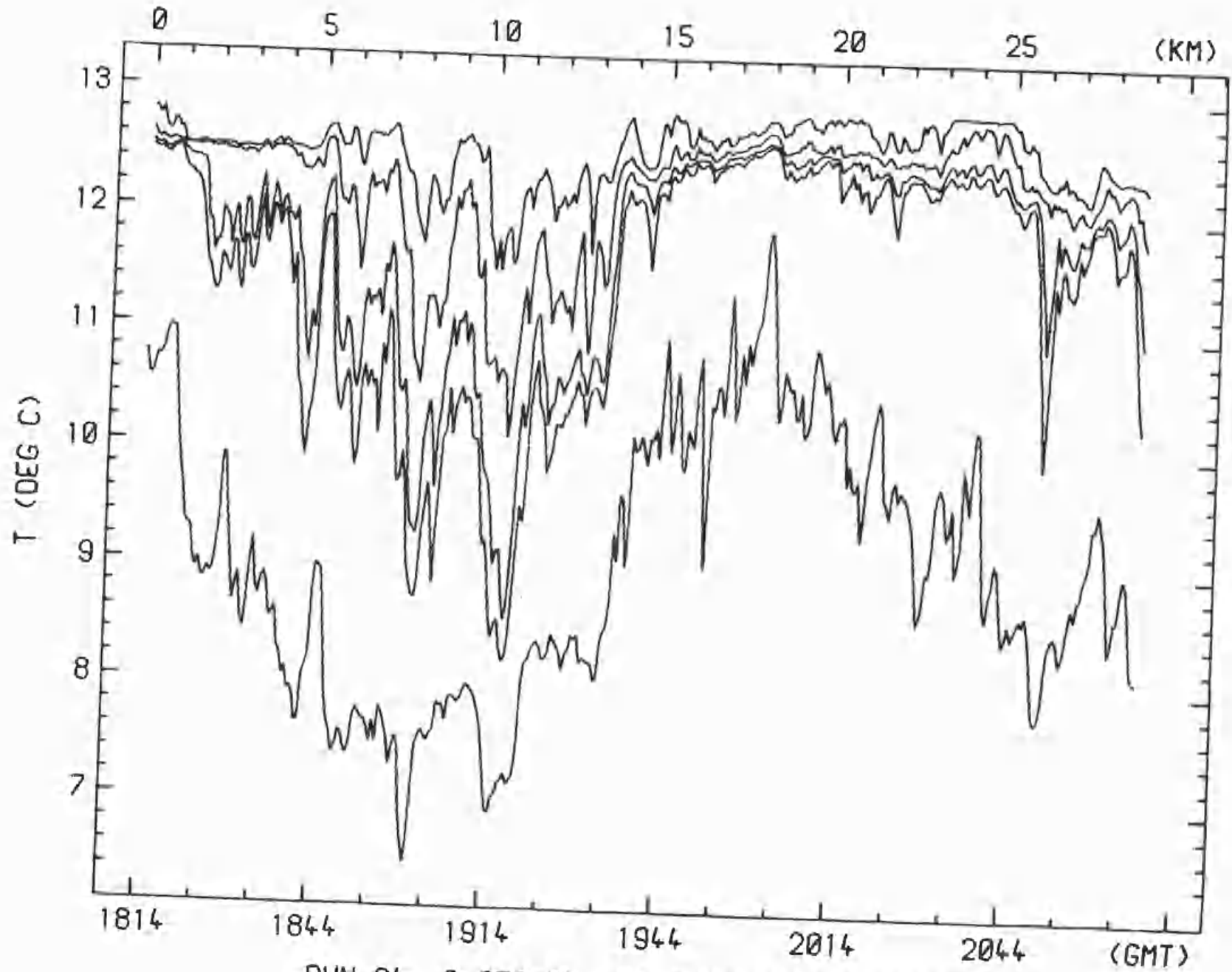
DEPTH = 20.6, 30.7, 32.8, 33.8, 40.1 M



49

RUN 23 6 SEP 77 TEMP VS TIME/DISTANCE
DEPTH = 27.5, 28.6, 30.7, 32.8, 33.8, 40.1 M

05



RUN 24 8 SEP 77 TEMP VS TIME/DISTANCE

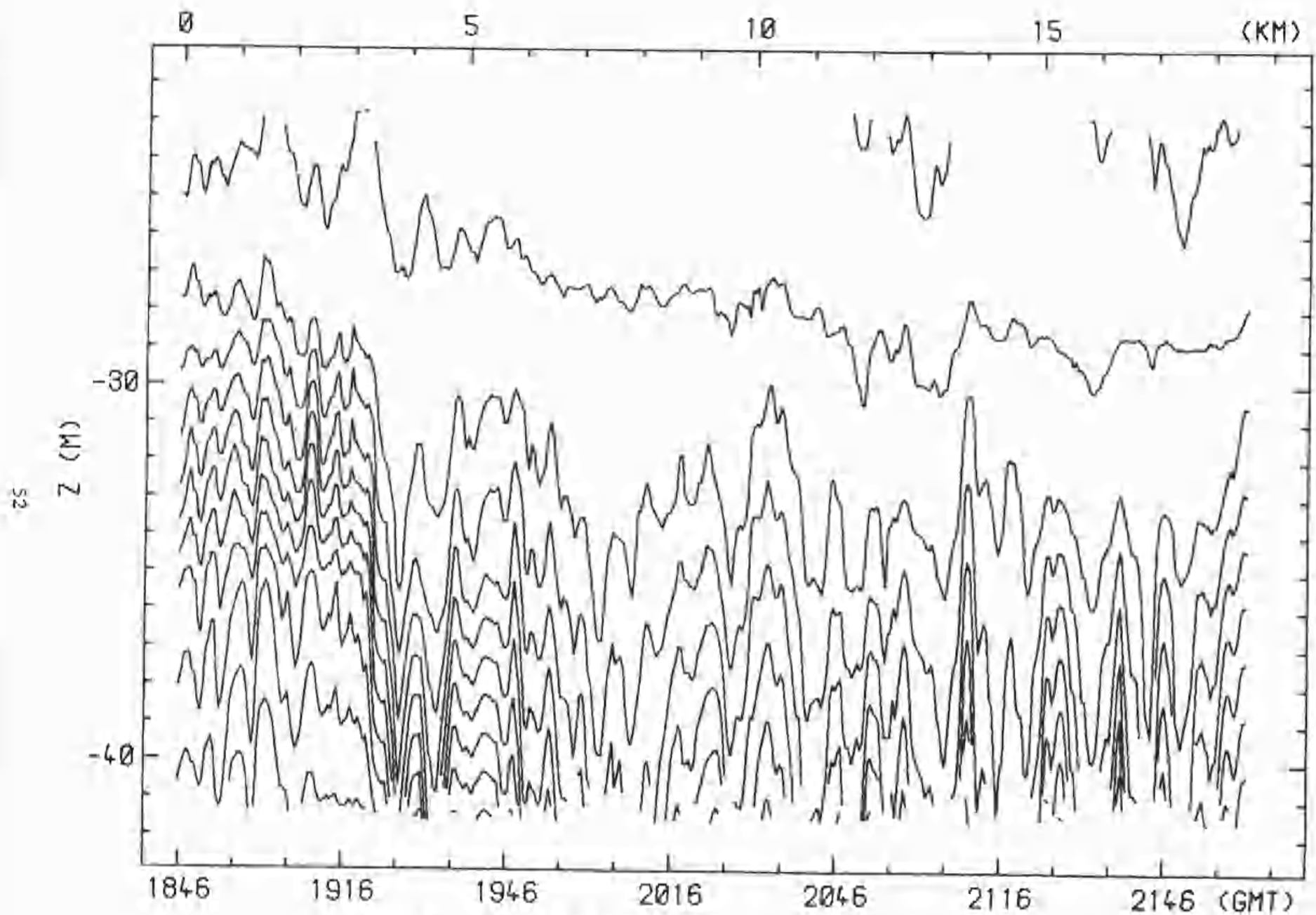
DEPTH = 29.7, 31.8, 33.9, 34.9, 41.2 M

APPENDIX C

Isotherm Cross-sections, 0.5°C Spacing

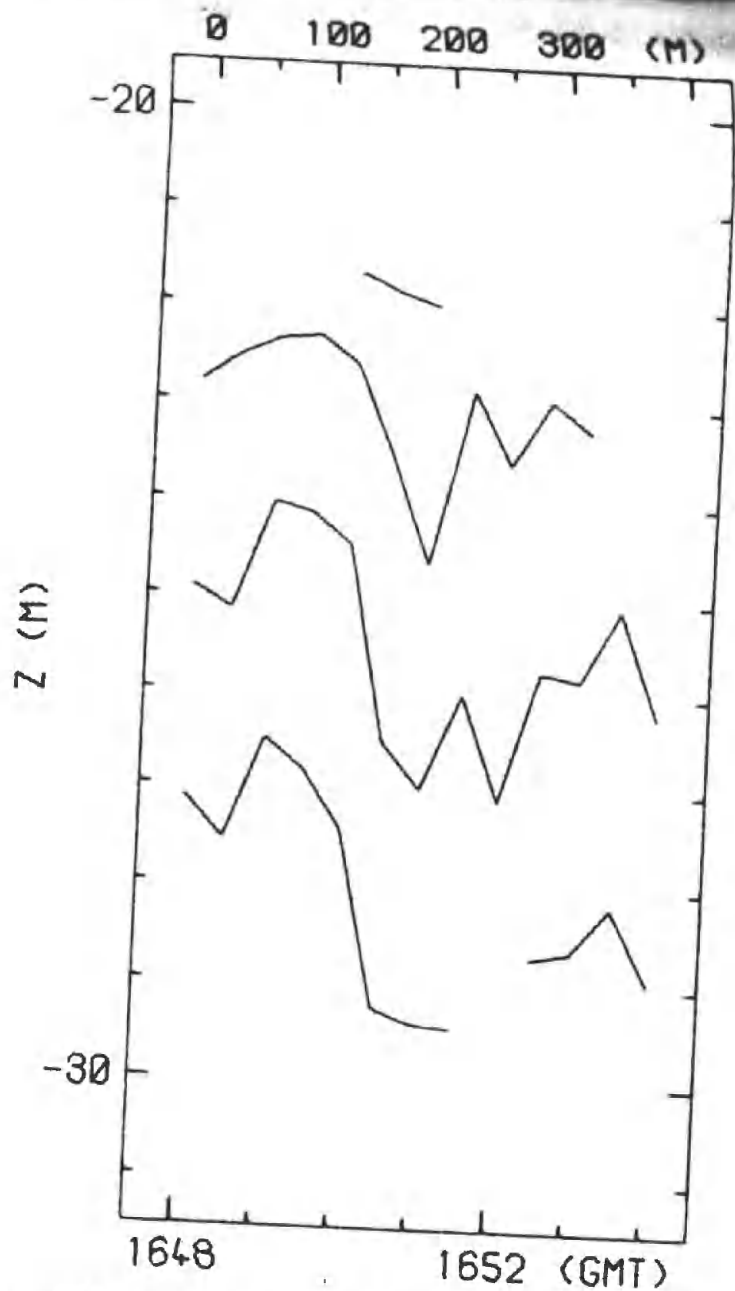
Isotherm depths, interpolated linearly from the temperatures plotted in Appendix B are plotted on the following pages.

VEFIM = 29.7, 31.8, 33.9, 36.9, 41.2 M



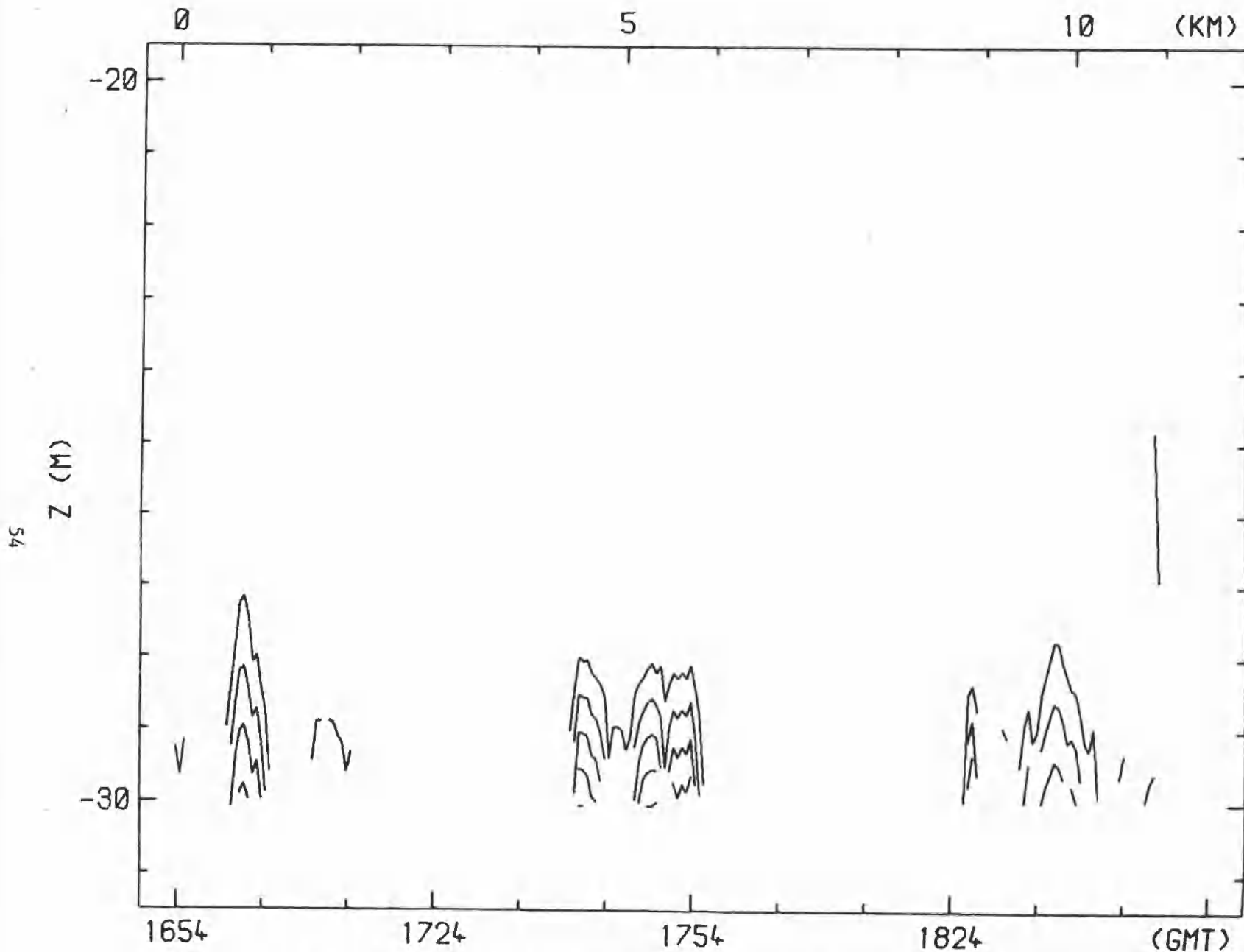
RUN 01 20 AUG 77 ISOTHERMS VS TIME/DISTANCE
T = 6.5 TO 12.0 DEG C IN 0.5 DEG INCREMENTS

T = 6.5 TO 12.0 DEG C IN 0.5 DEG INCREMENTS



RUN 02 22 AUG 77 ISOTHERMS VS TIME/DISTANCE

T = 11.0 TO 12.5 DEG C IN 0.5 DEG INCREMENTS

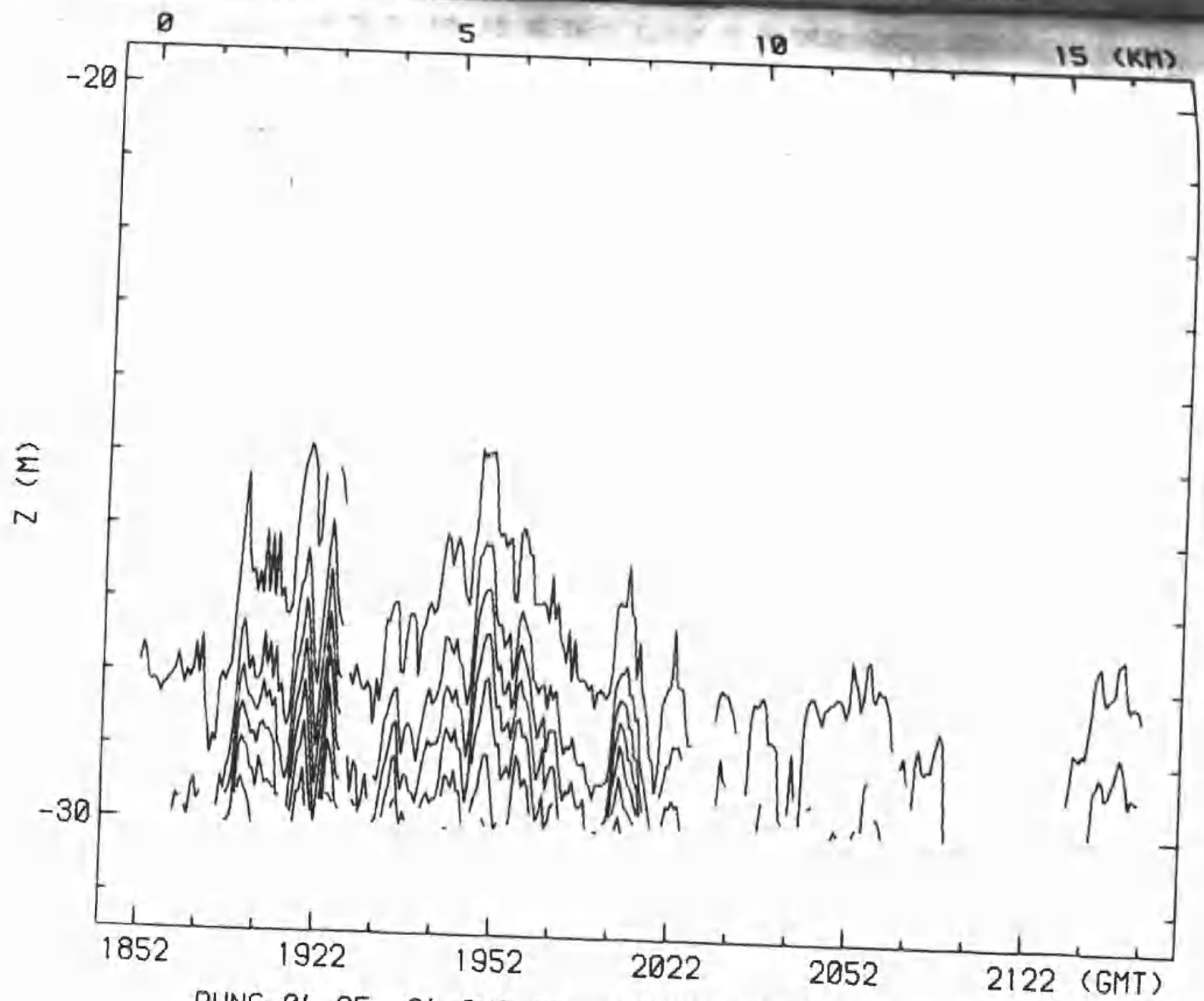


RUN 03 24 AUG 77 ISOTHERMS VS TIME/DISTANCE

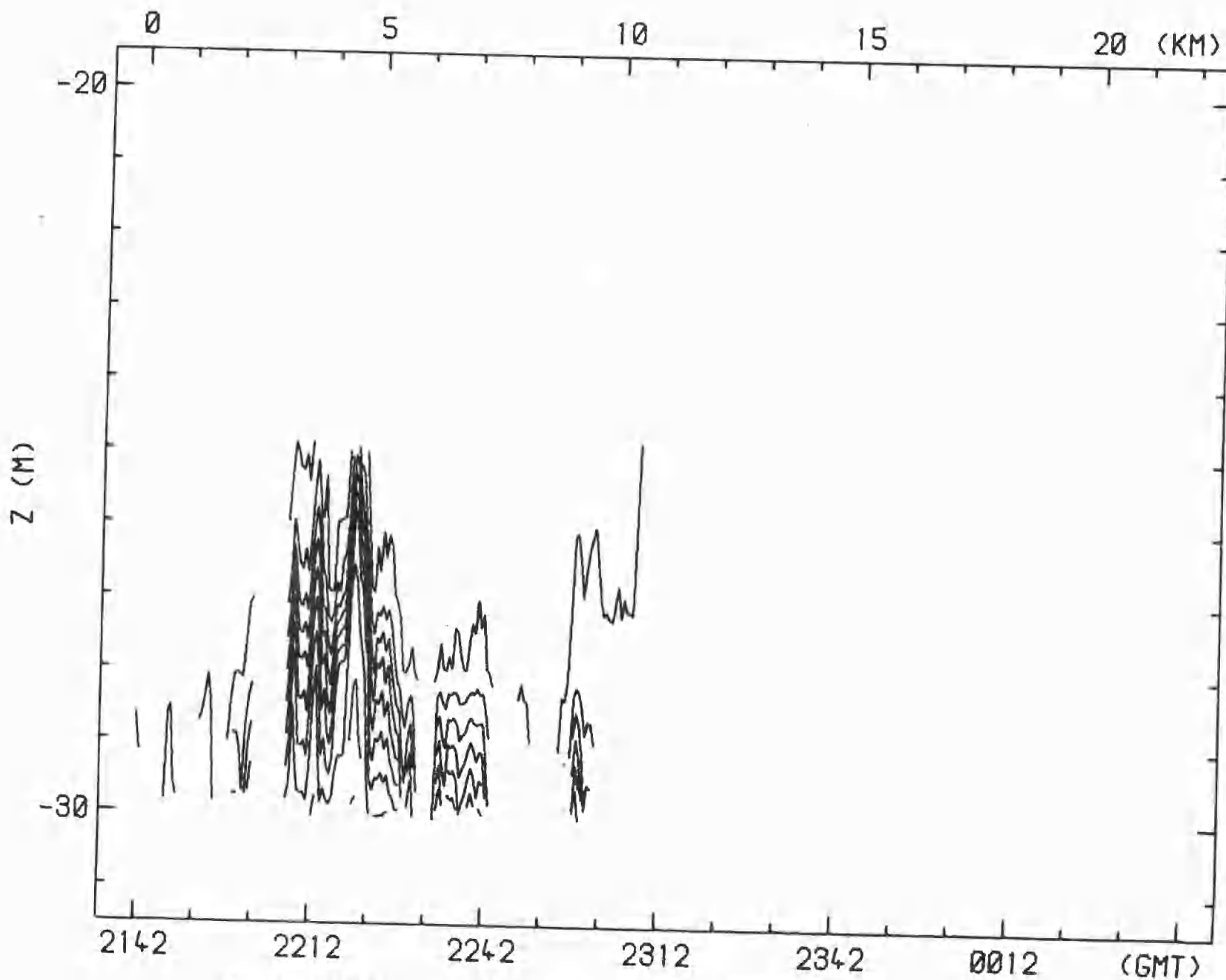
T = 9.5 TO 12.0 DEG C IN 0.5 DEG INCREMENTS

T = 9.5 TO 12.0 DEG C IN 0.5 DEG INCREMENTS

55

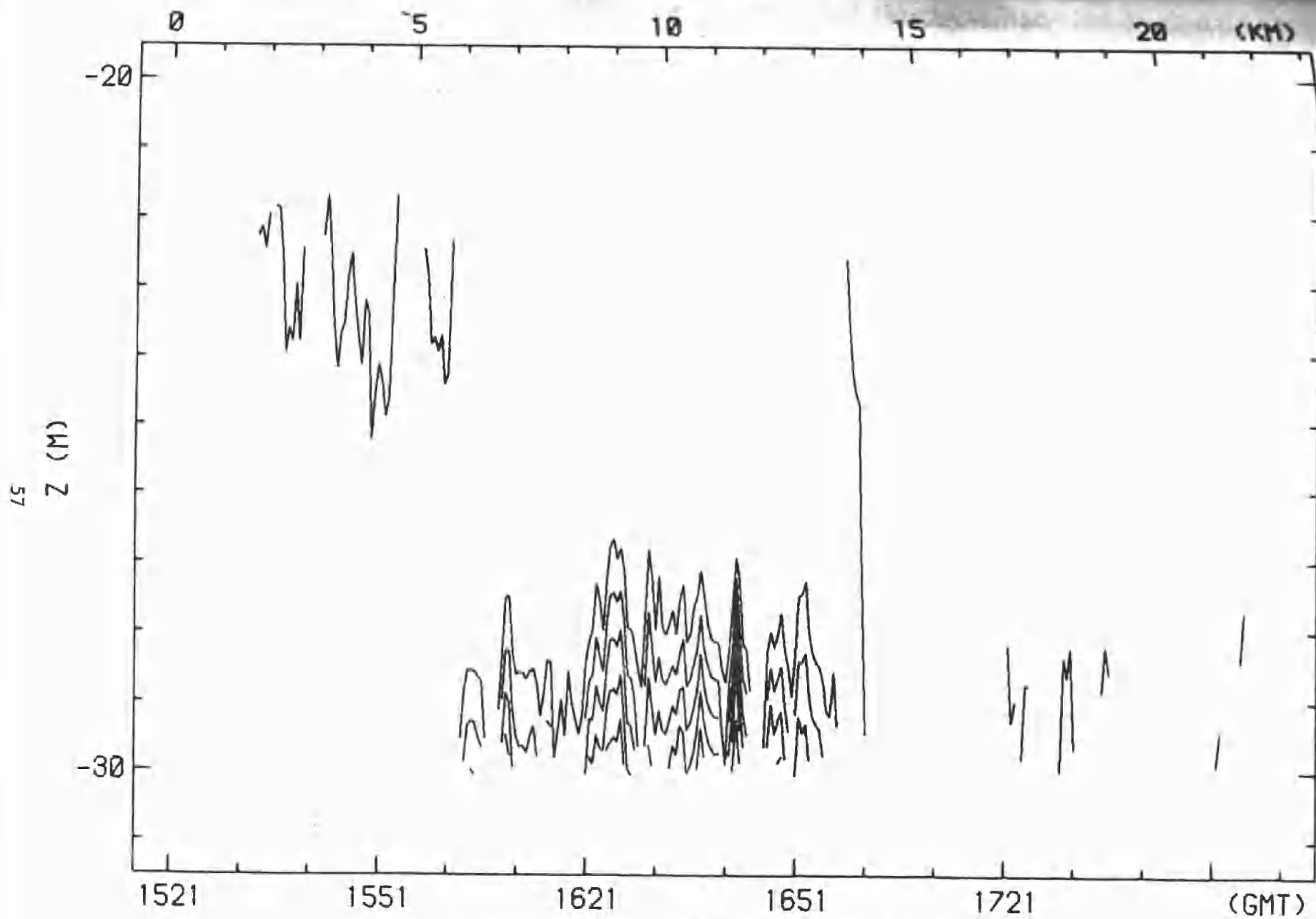


RUNS 04-05 24 AUG 77 ISOTHERMS VS TIME/DISTANCE
T = 8.5 TO 12.0 DEG C IN 0.5 DEG INCREMENTS

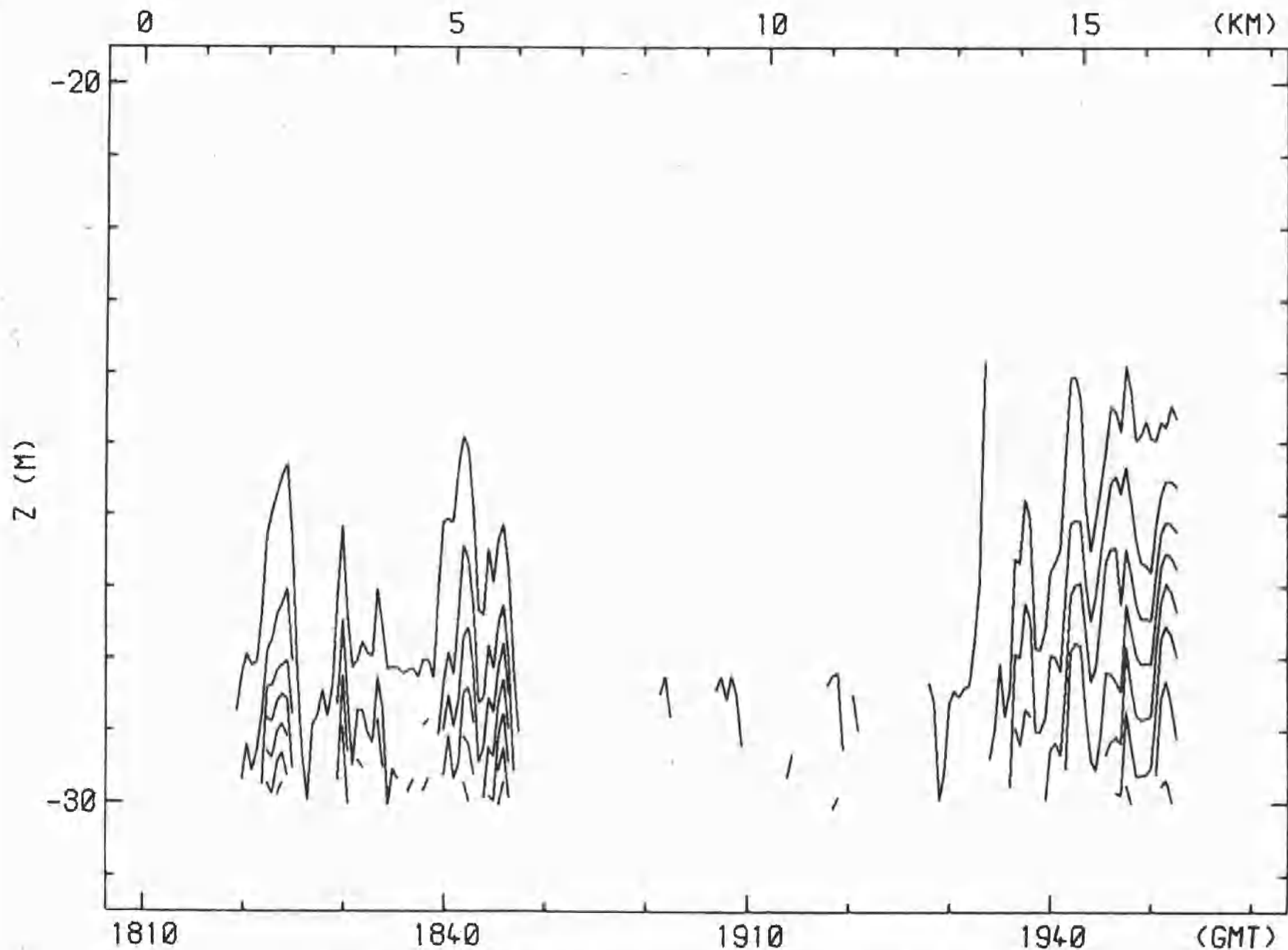


RUNS 05-06 24 AUG 77 ISOTHERMS VS TIME/DISTANCE

T = 7.5, 10, 12, 15 DEG IN 2-5 DEG

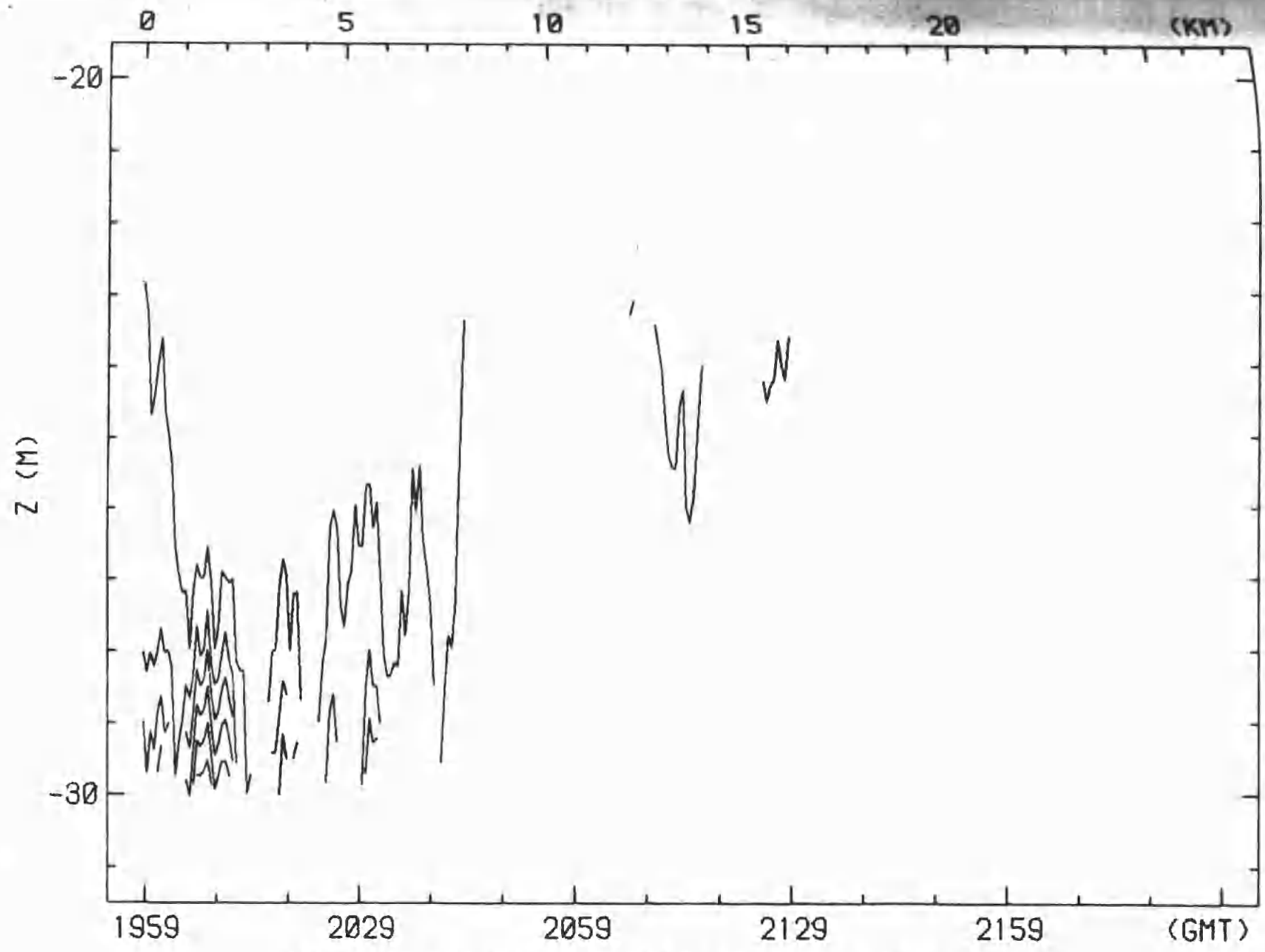


RUN 07 26 AUG 77 ISOTHERMS VS TIME/DISTANCE
T = 9.0 TO 12.0 DEG C IN 0.5 DEG INCREMENTS



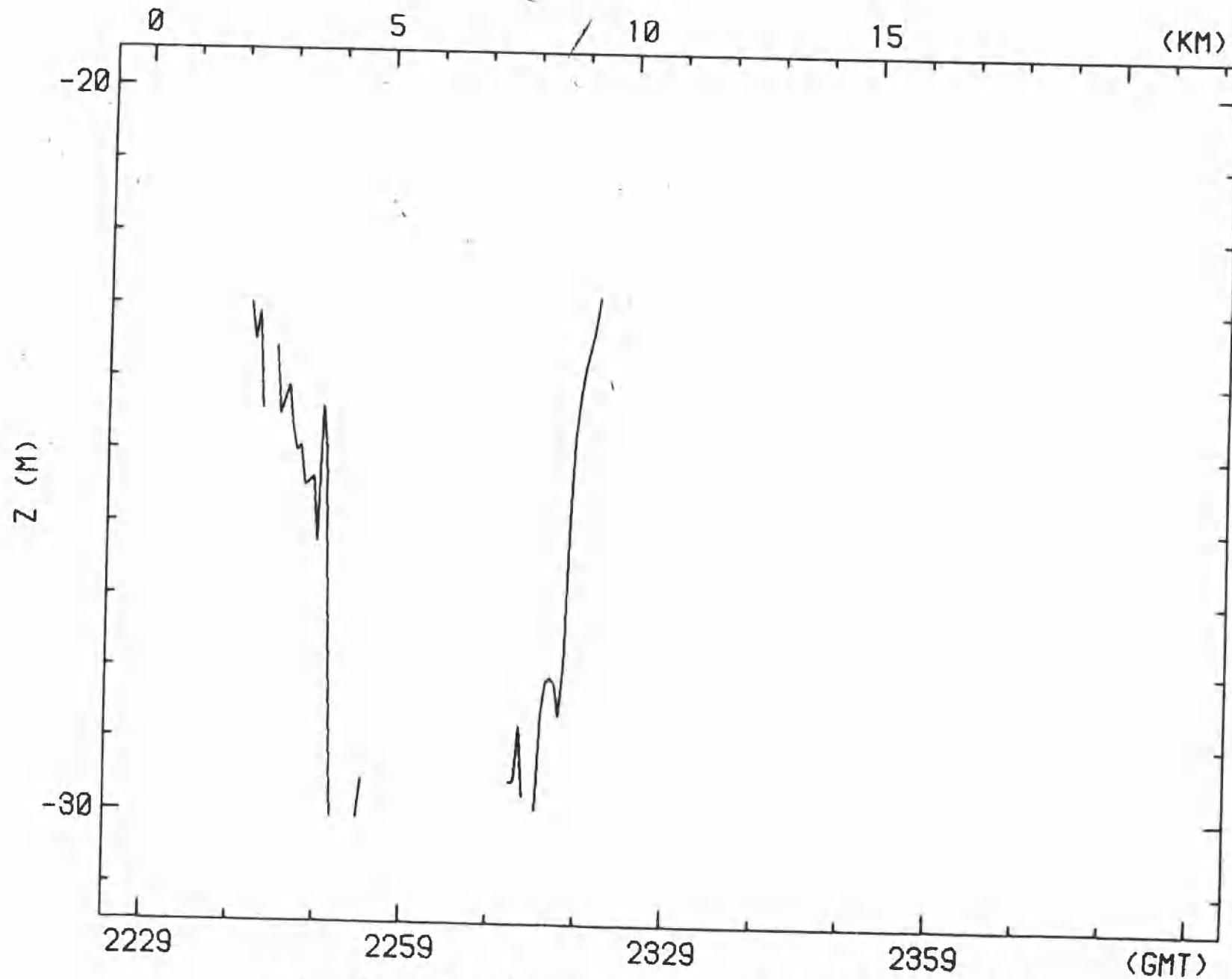
RUN 08 26 AUG 77 ISOTHERMS VS TIME/DISTANCE

T = 8.0 TO 12.0 DEG C IN 0.5 DEG INCREMENTS



RUN 09 26 AUG 77 ISOTHERMS VS TIME/DISTANCE
T = 9.0 TO 12.0 DEG C IN 0.5 DEG INCREMENTS

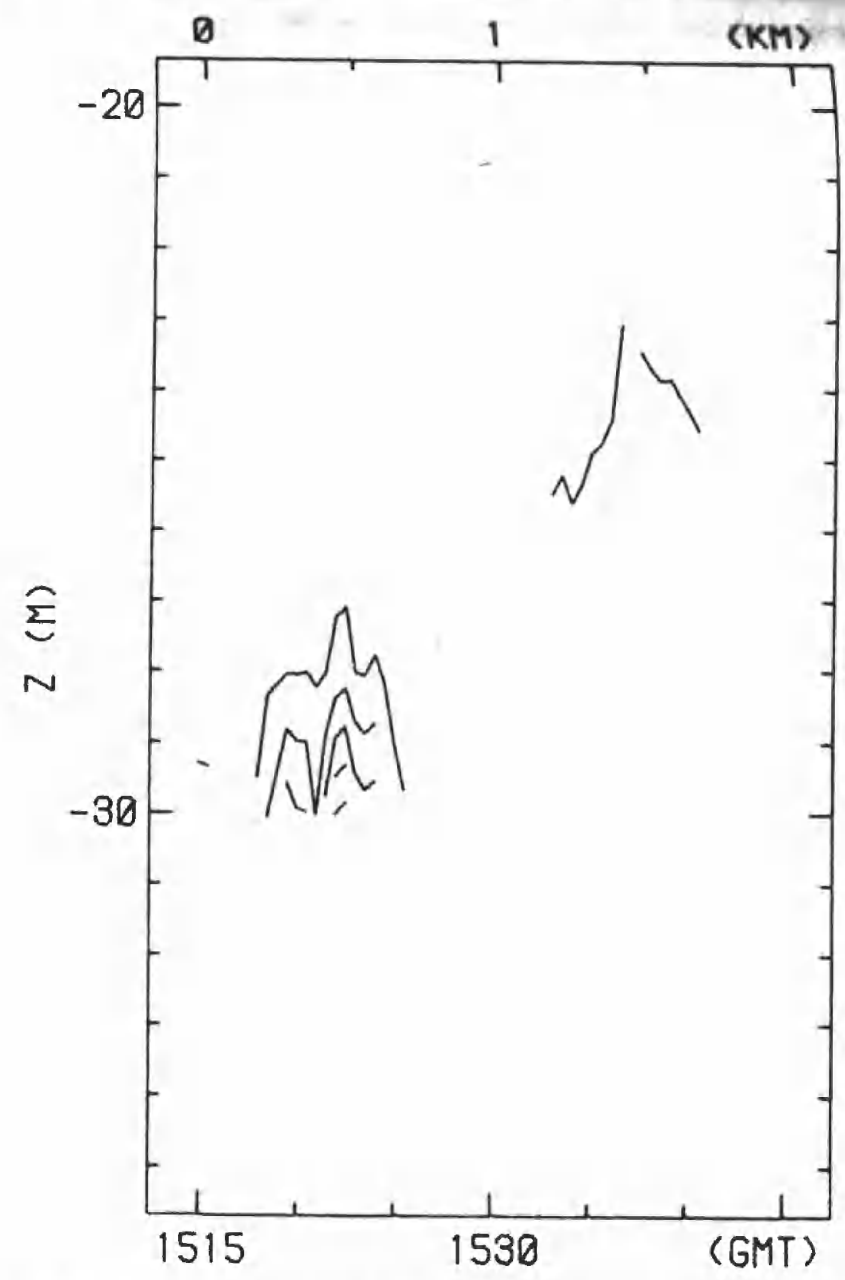
09



RUN 09 26 AUG 77 ISOTHERM VS TIME/DISTANCE

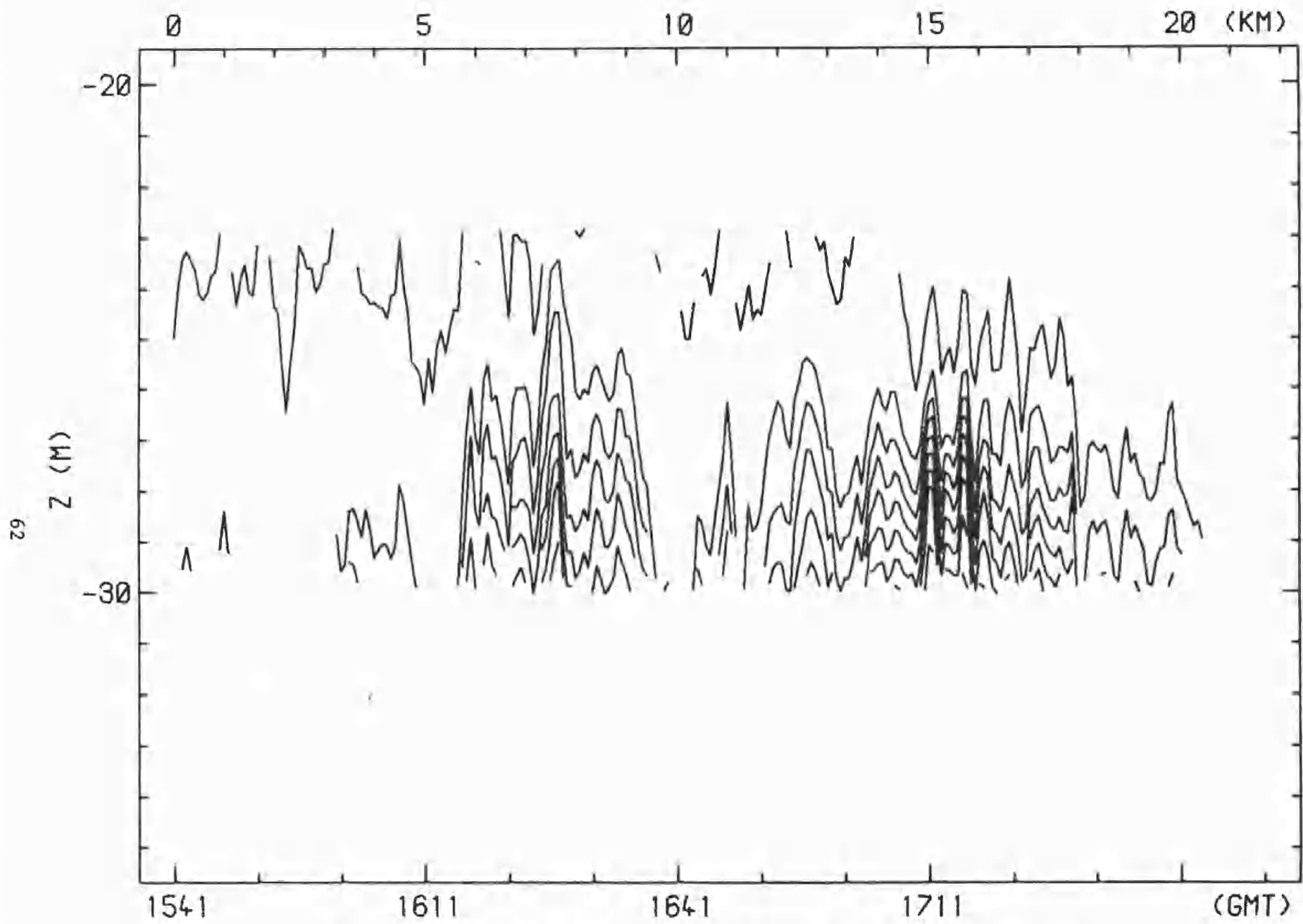
T = 12.0 DEG C

T = 12.0 DEG C



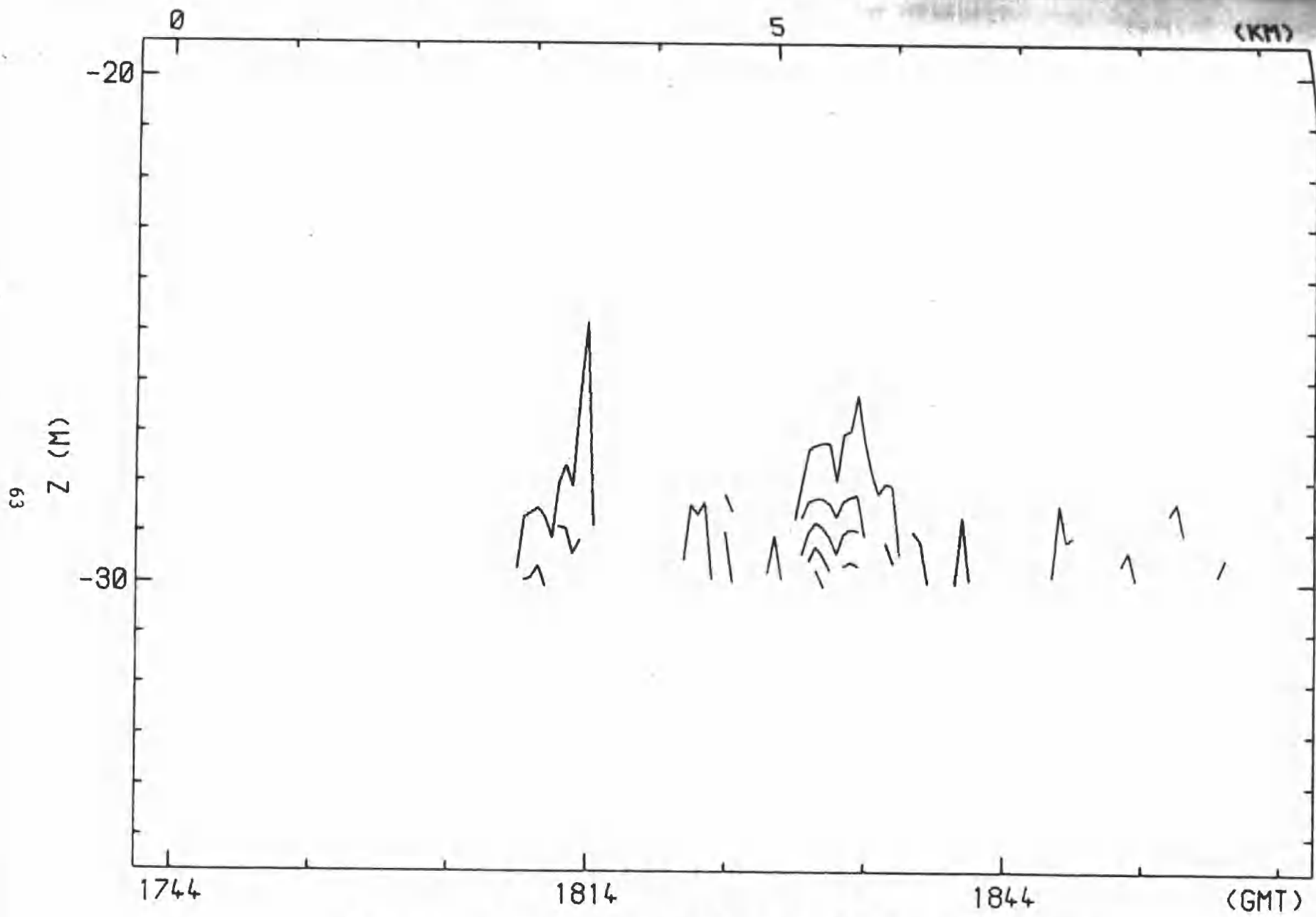
RUNS 10-11 28 AUG 77 ISOTHERMS VS TIME/DISTANCE
T = 9.5 TO 12.0 DEG C IN 0.5 DEG INCREMENTS

19



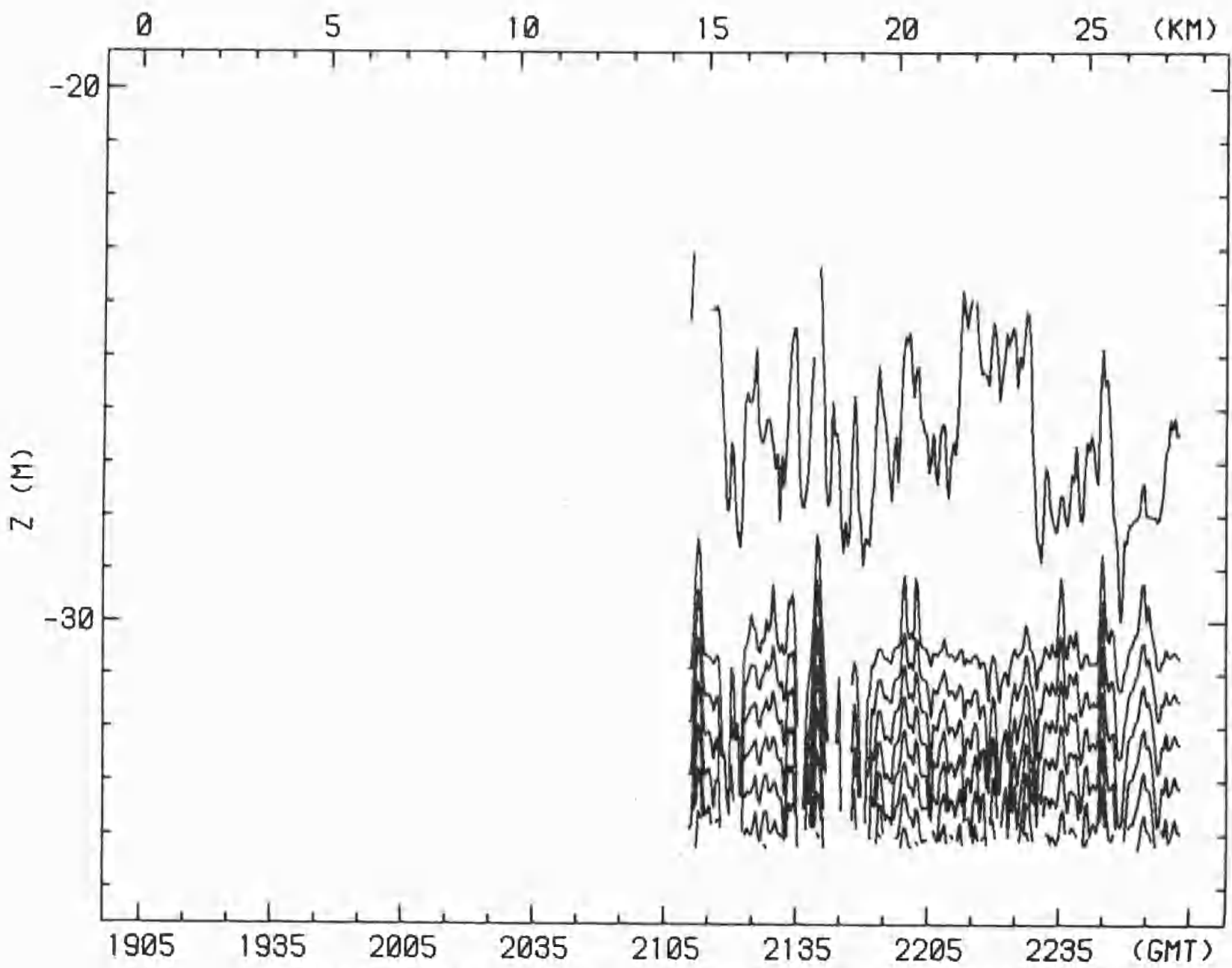
RUN 11 28 AUG 77 ISOTHERMS VS TIME/DISTANCE

T = 8.0 TO 12.0 DEG C IN 0.5 DEG INCREMENTS



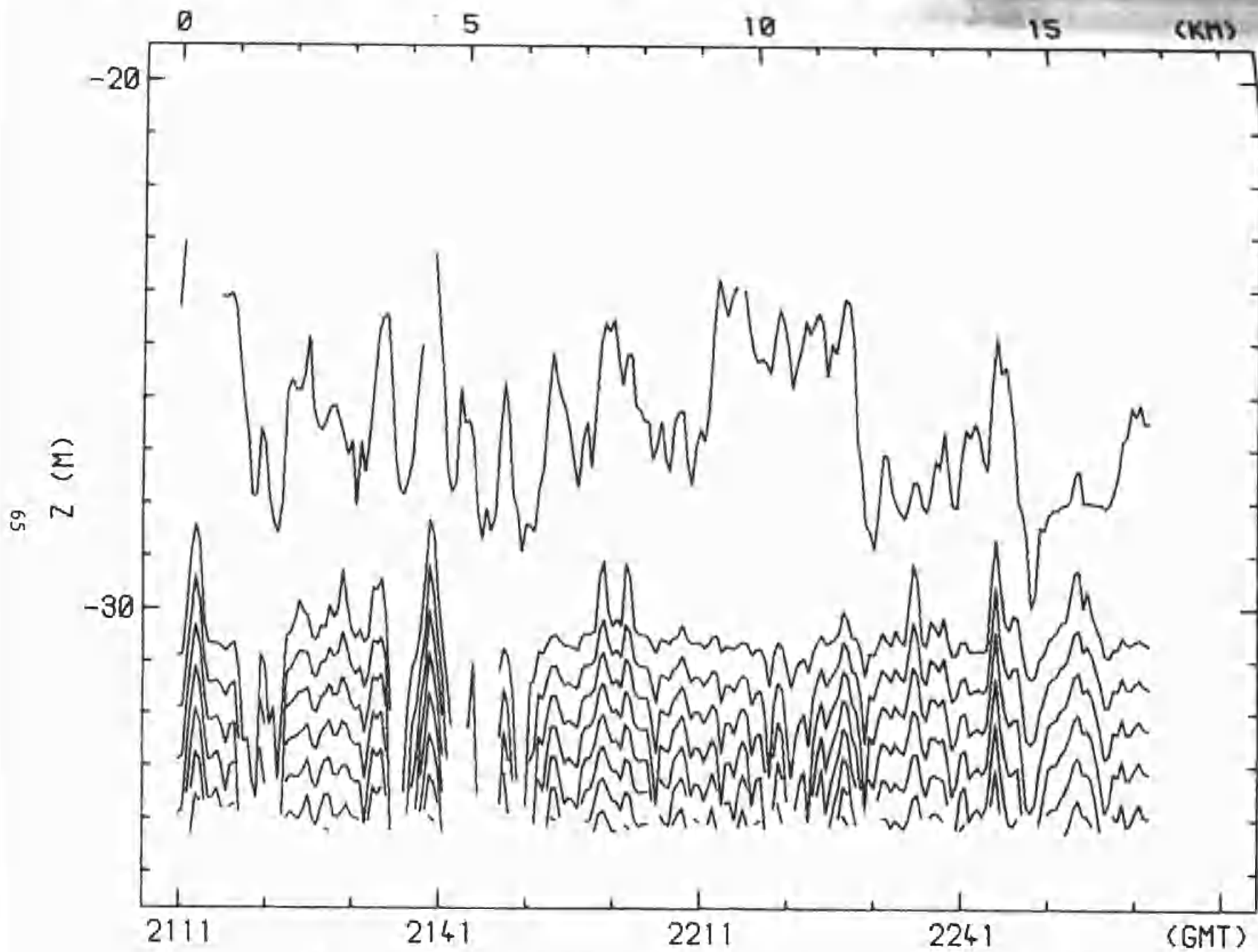
RUN 11 28 AUG 77 ISOTHERMS VS TIME/DISTANCE
T = 10.0 TO 12.0 DEG C IN 0.5 DEG INCREMENTS

49

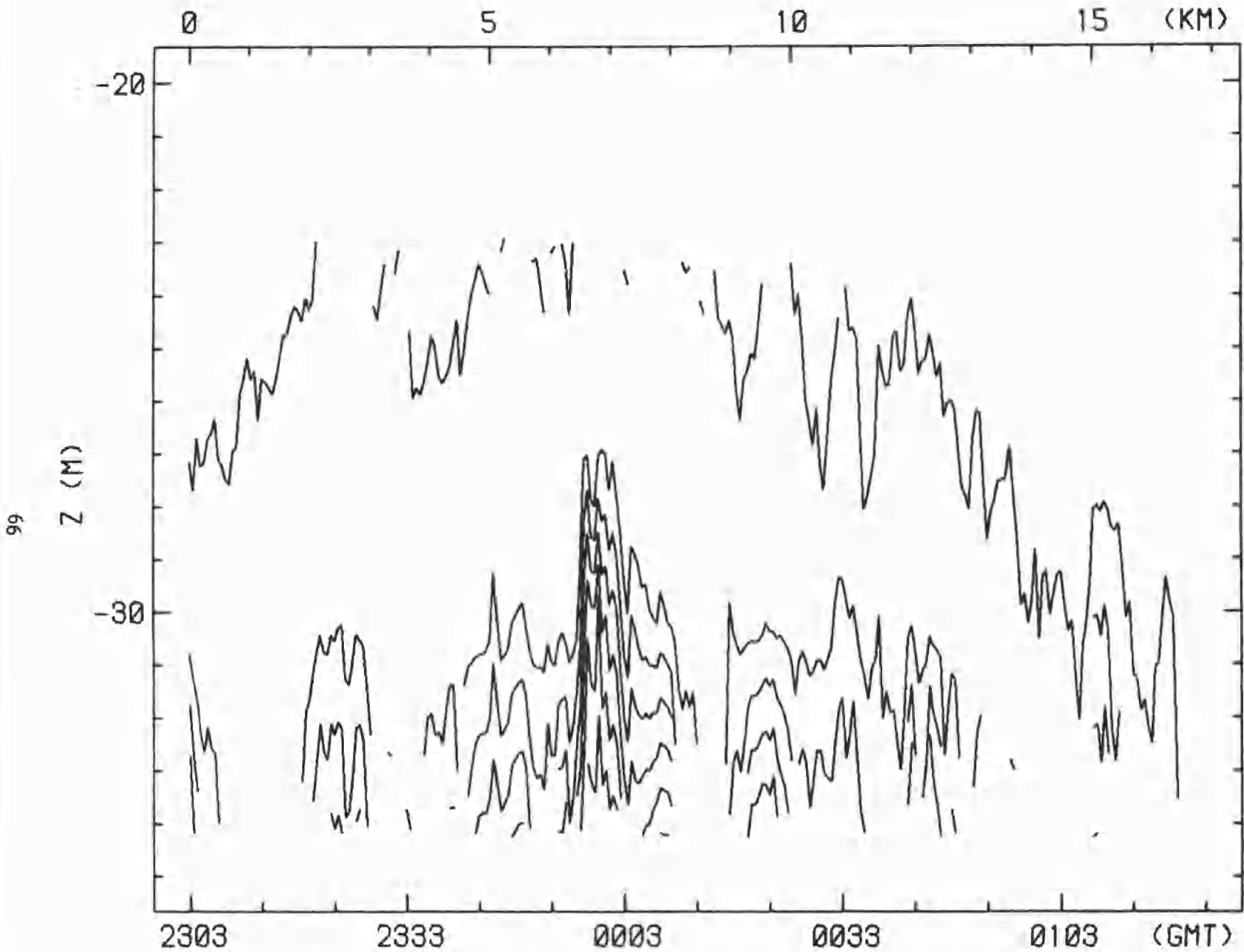


RUNS 11-12 28 AUG 77 ISOTHERMS VS TIME/DISTANCE

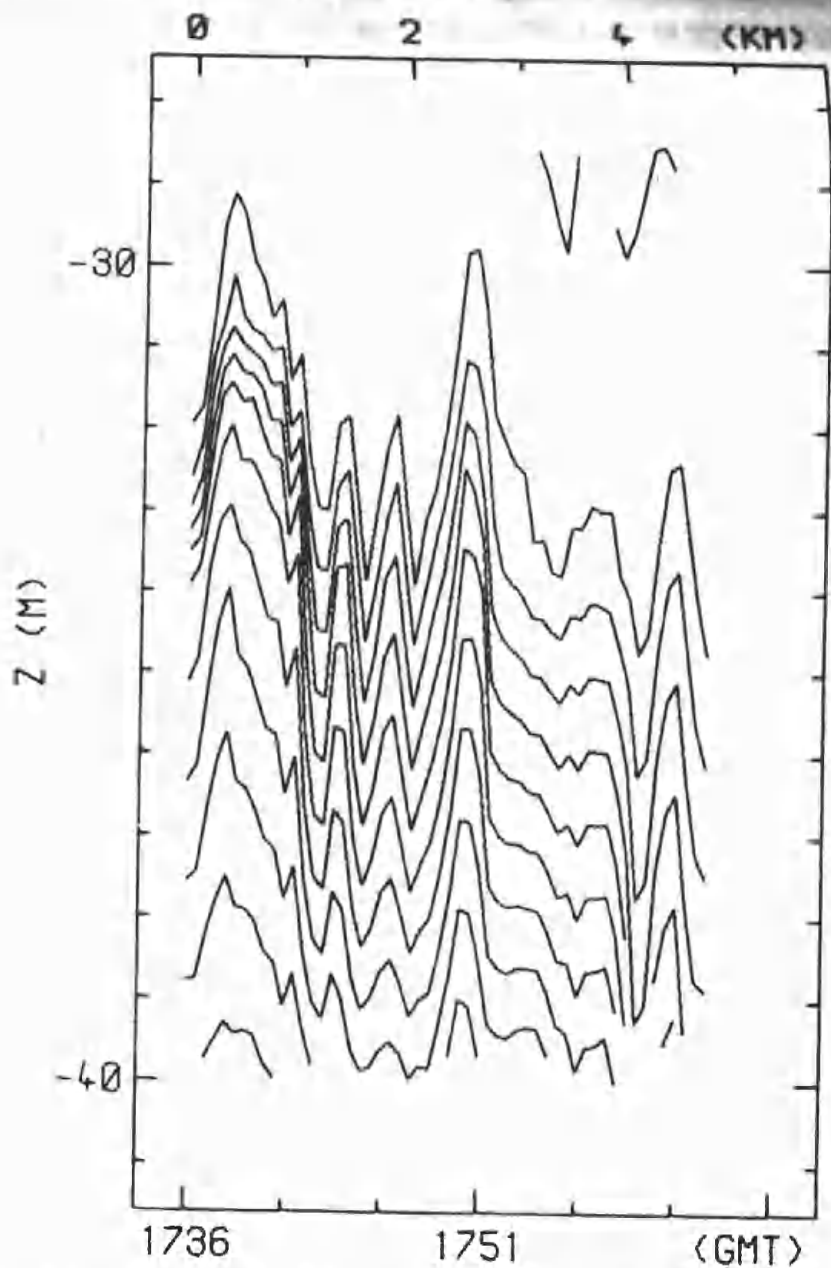
T = 8.0 TO 12.0 DEG C IN 0.5 DEG INCREMENTS



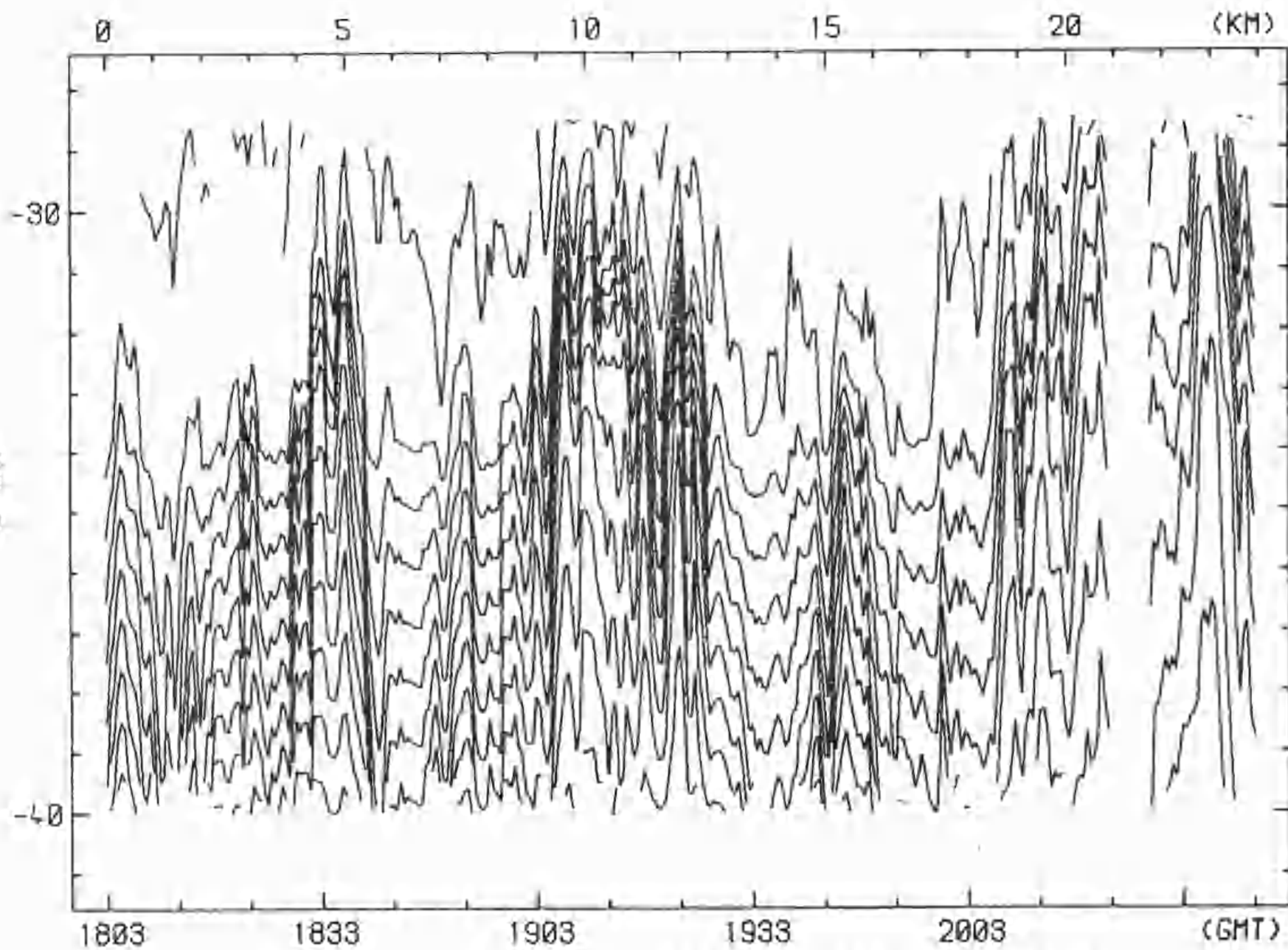
RUN 12 28 AUG 77 ISOTHERMS VS TIME/DISTANCE
T = 8.0 TO 12.0 DEG C IN 0.5 DEG INCREMENTS



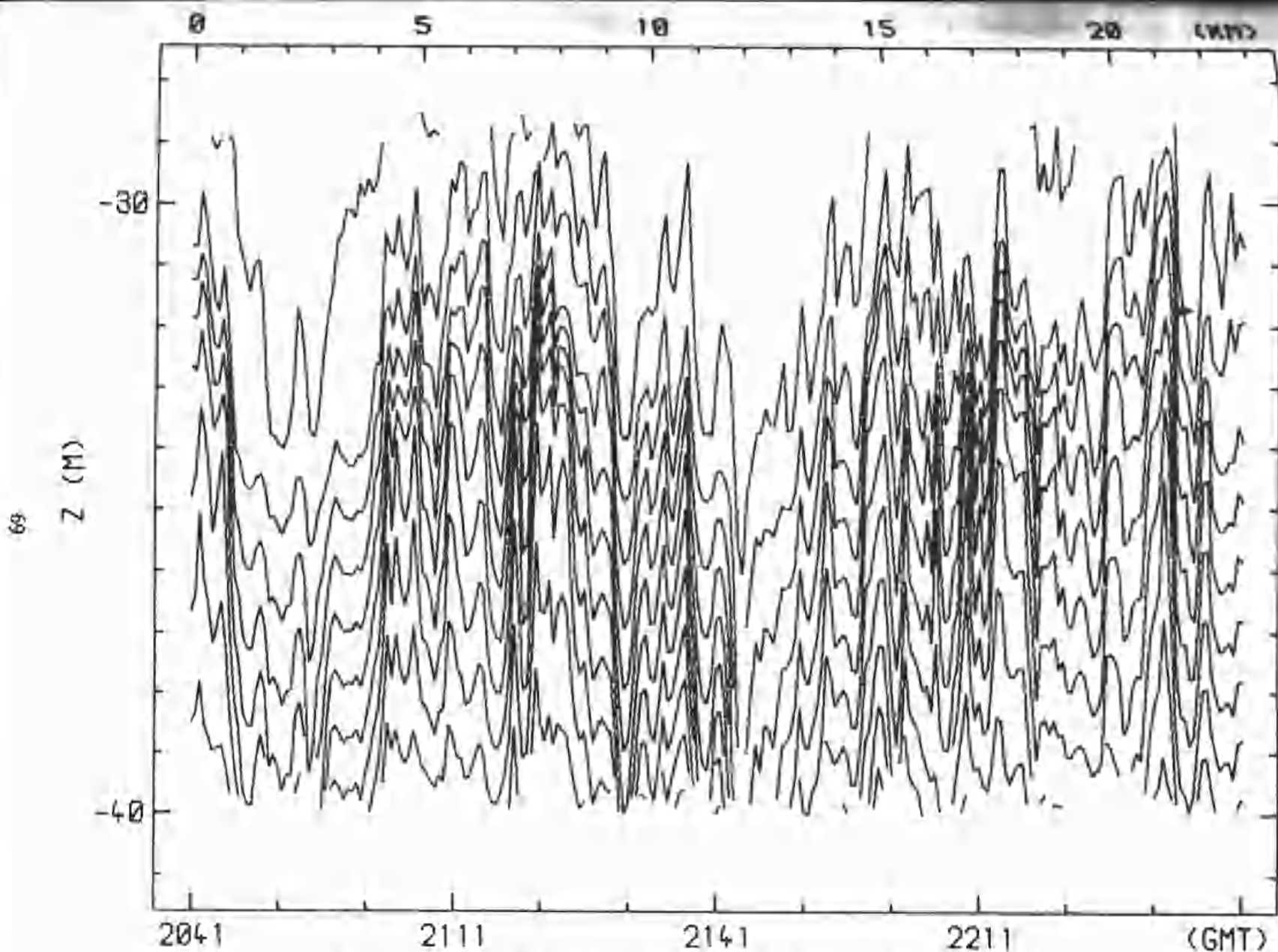
RUN 12 28 AUG 77 ISOTHERMS VS TIME/DISTANCE
T = 9.0 TO 12.0 DEG C IN 0.5 DEG INCREMENTS



RUN 13 30 AUG 77 ISOTHERMS VS TIME/DISTANCE
T = 6.5 TO 12.0 DEG C IN 0.5 DEG INCREMENTS

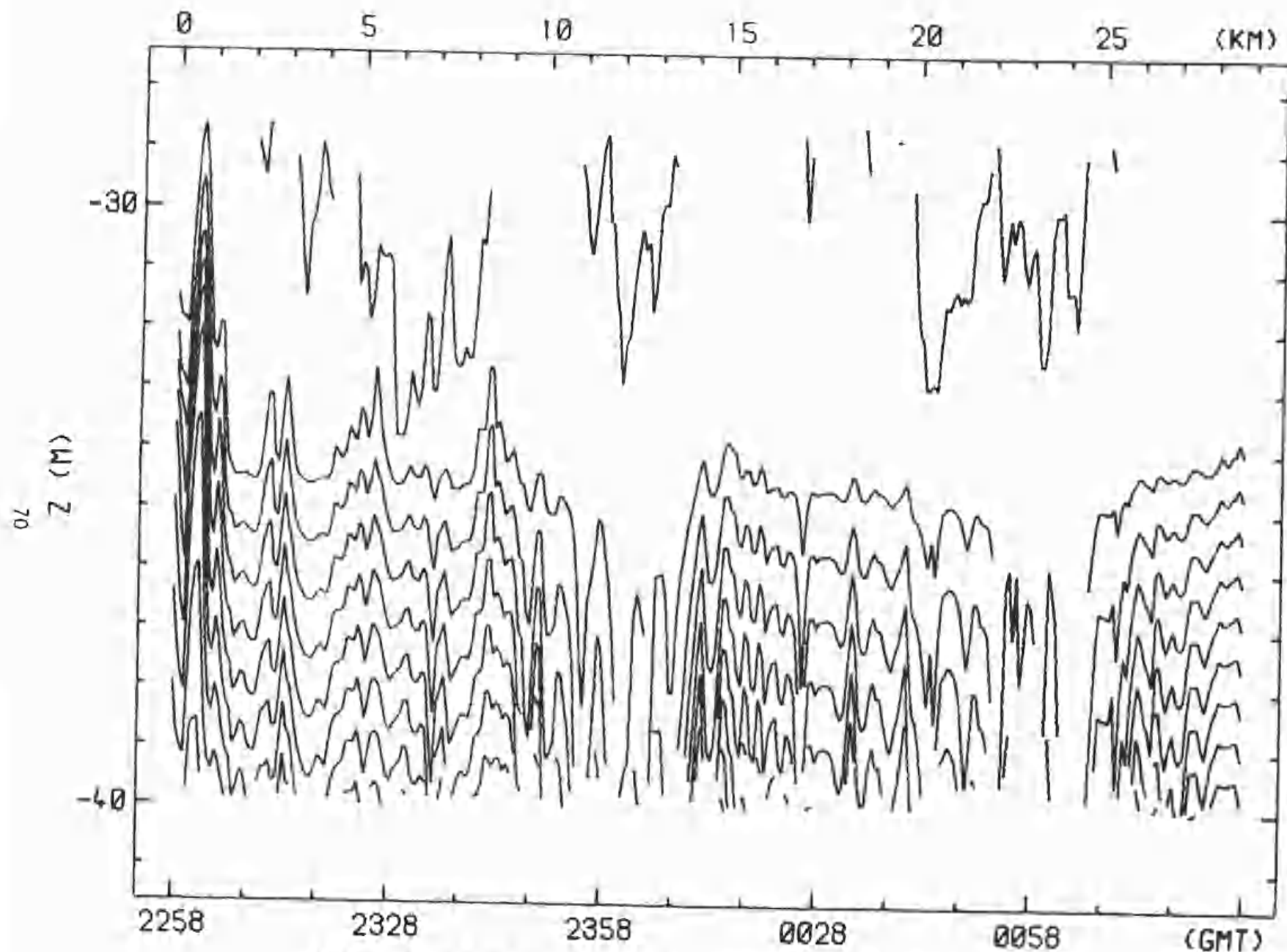


RUNS 13-14 30 AUG 77 ISOTHERMS VS TIME/DISTANCE
T = 6.5 TO 12.0 DEG C IN 0.5 DEG INCREMENTS



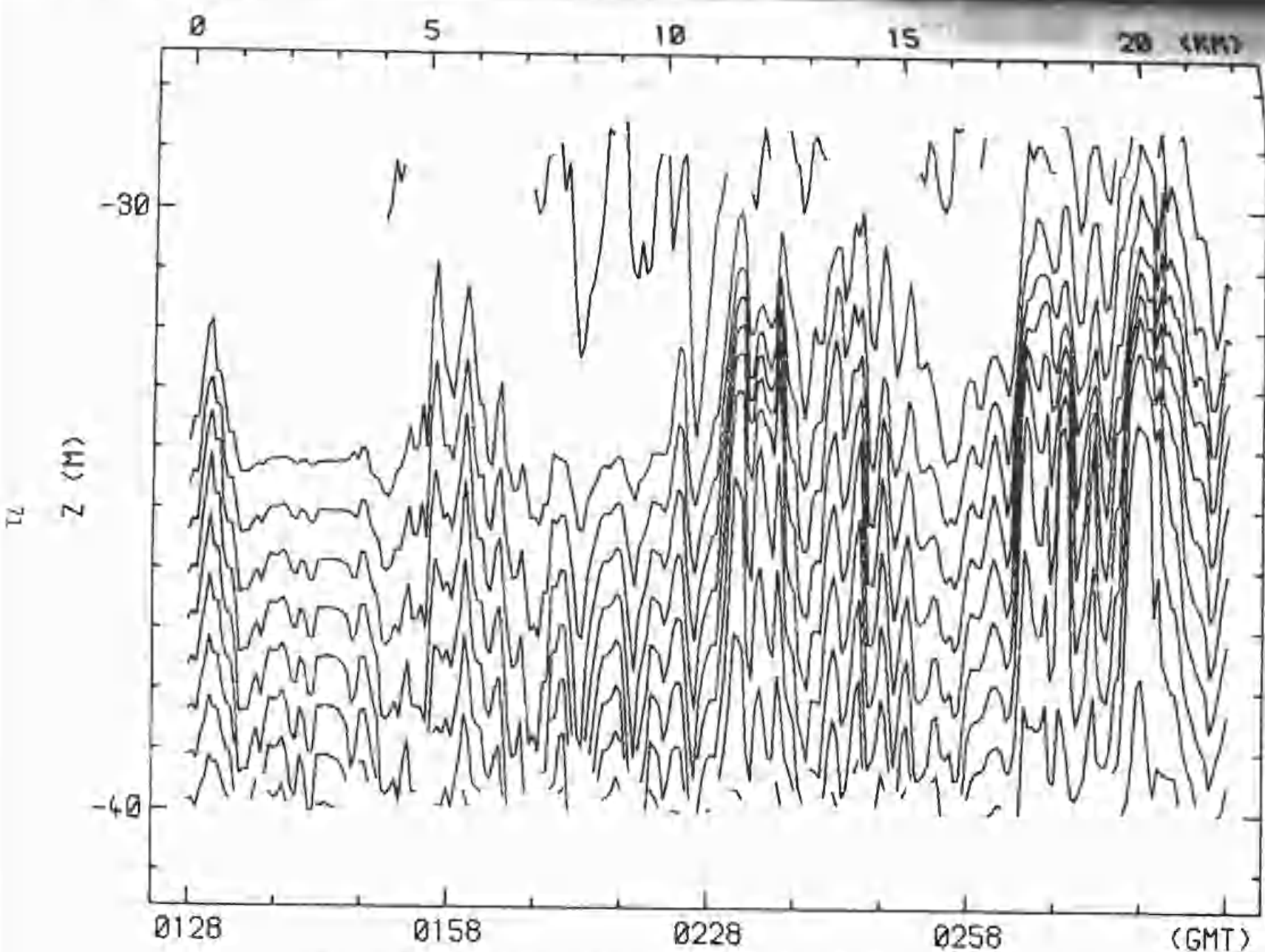
RUN 14 30 AUG 77 ISOTHERMS VS TIME/DISTANCE

T = 6.5 TO 12.0 DEG C IN 0.5 DEG INCREMENTS

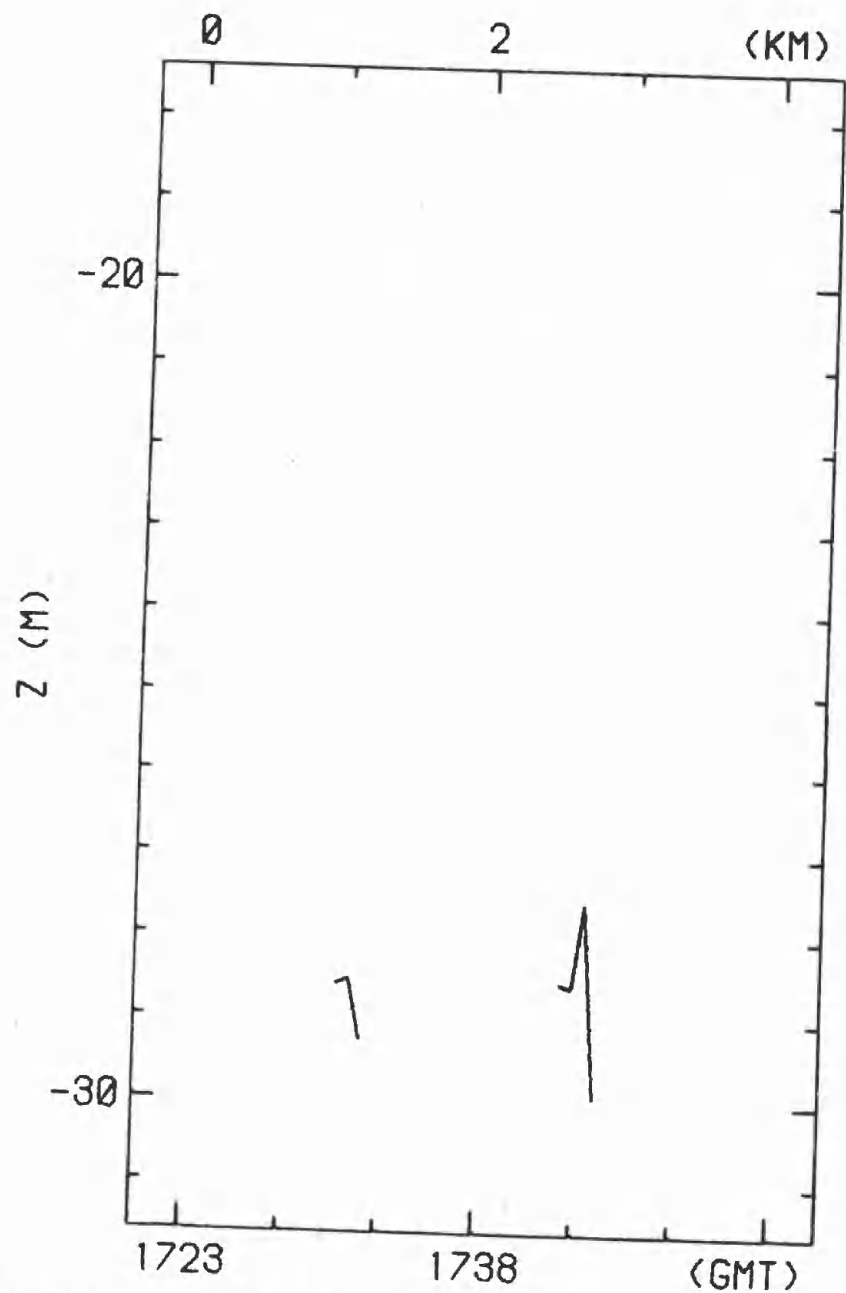


RUN 15 30 AUG 77 ISOTHERMS VS TIME/DISTANCE

T = 7.5 TO 12.0 DEG C IN 0.5 DEG INCREMENTS

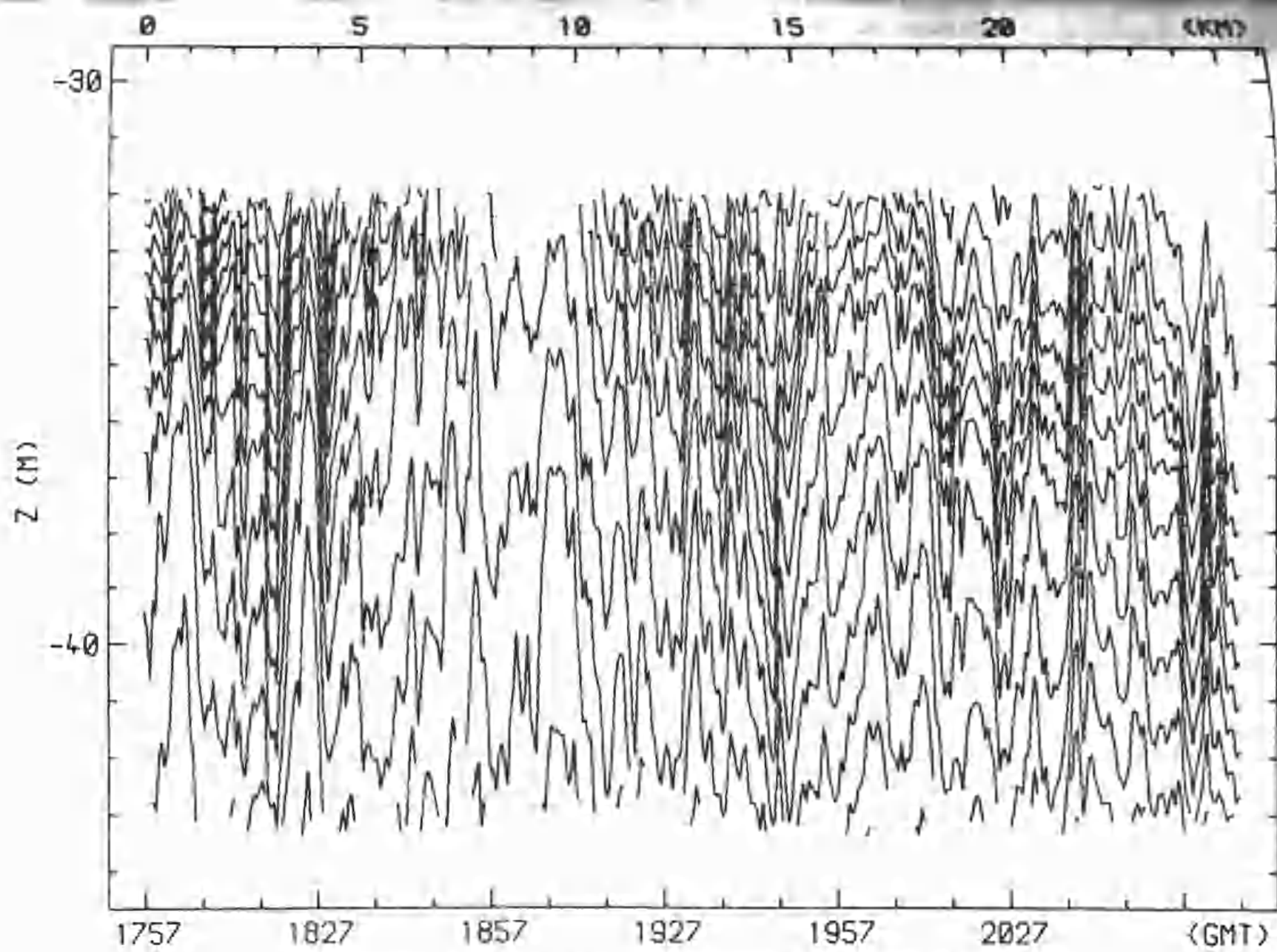


RUN 15 31 AUG 77 ISOTHERMS VS TIME/DISTANCE
T = 6.5 TO 12.0 DEG C IN 0.5 DEG INCREMENTS



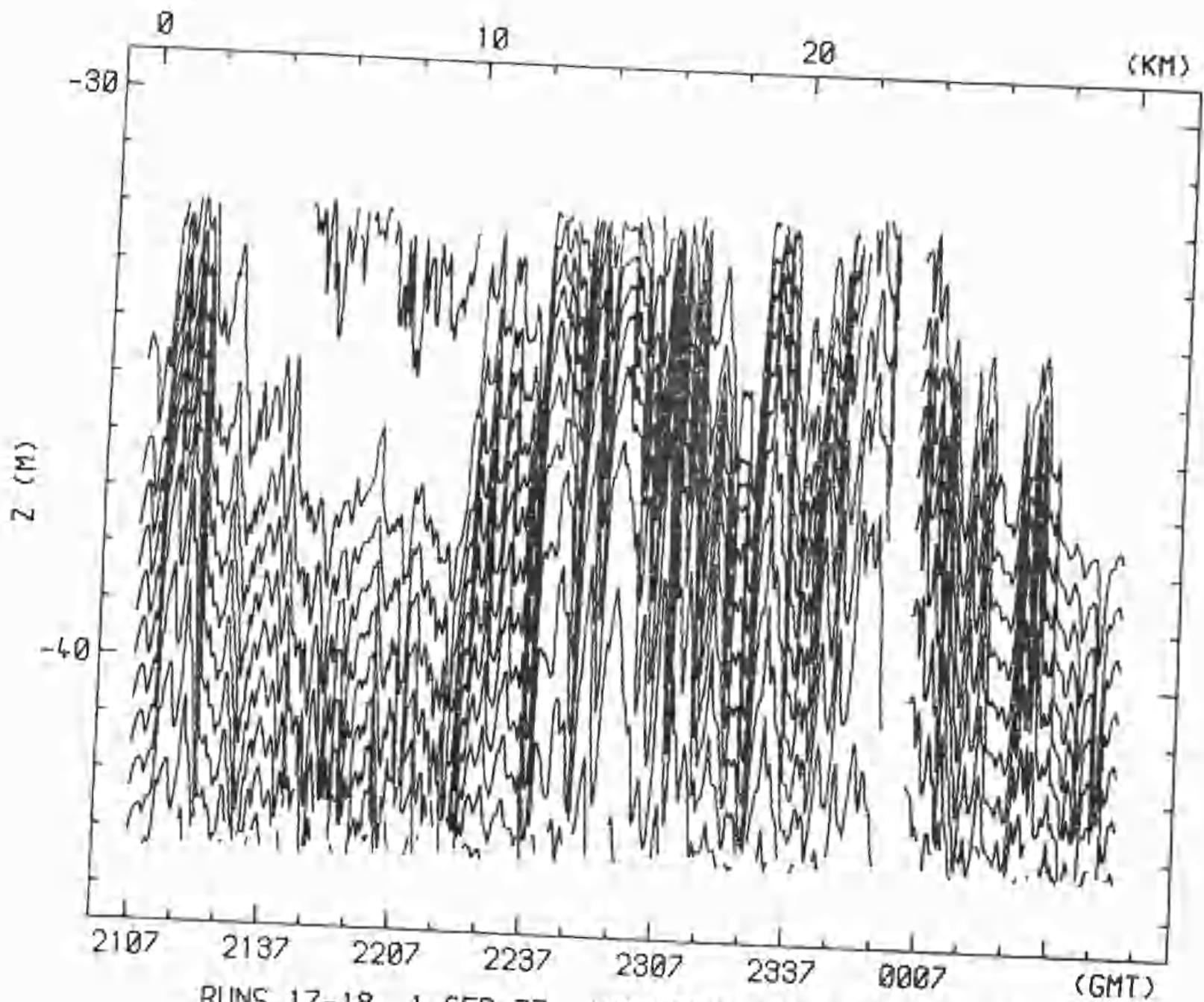
RUN 16 1 SEP 77 ISOTHERM VS TIME/DISTANCE

T = 12.0 DEG C



RUN 17 1 SEP 77 ISOTHERMS VS TIME/DISTANCE
T = 6.0 TO 12.0 DEG C IN 0.5 DEG INCREMENTS

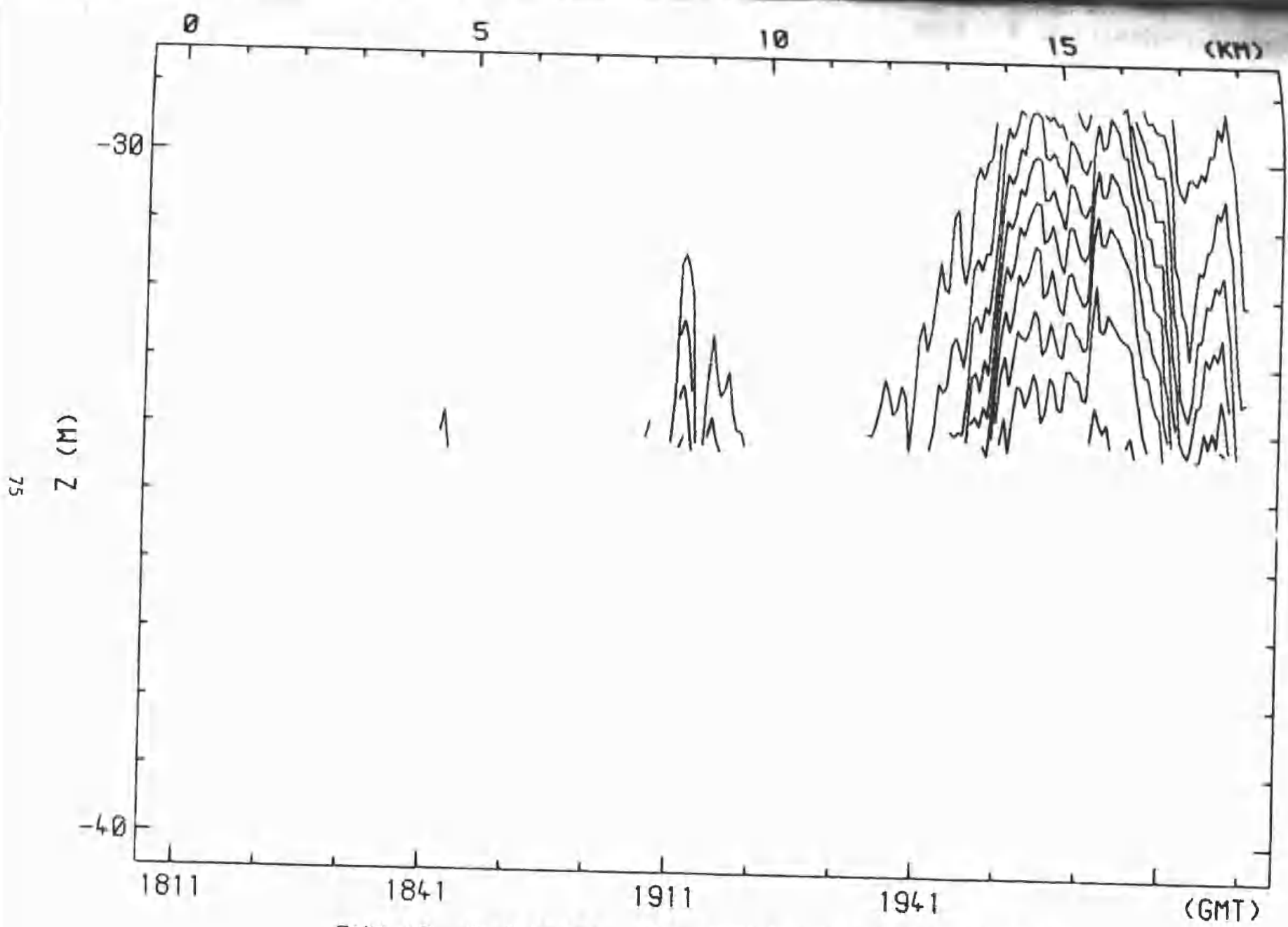
74



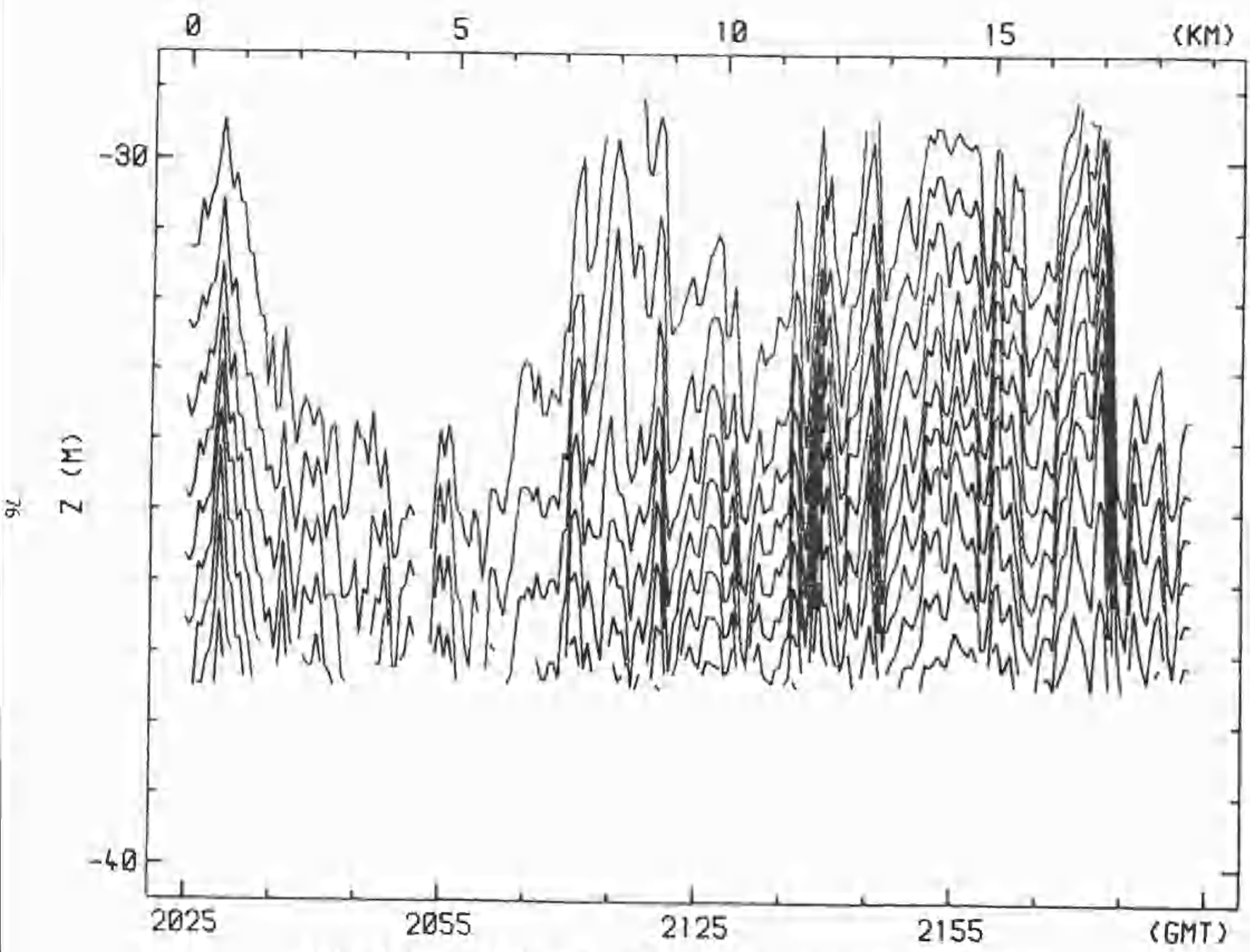
RUNS 17-18 1 SEP 77 ISOTHERMS VS TIME/DISTANCE

T = 6.5 TO 12.5 DEG C IN 0.5 DEG INCREMENTS

10-12 DEGC IN 0.5 DEG INCREMENTS

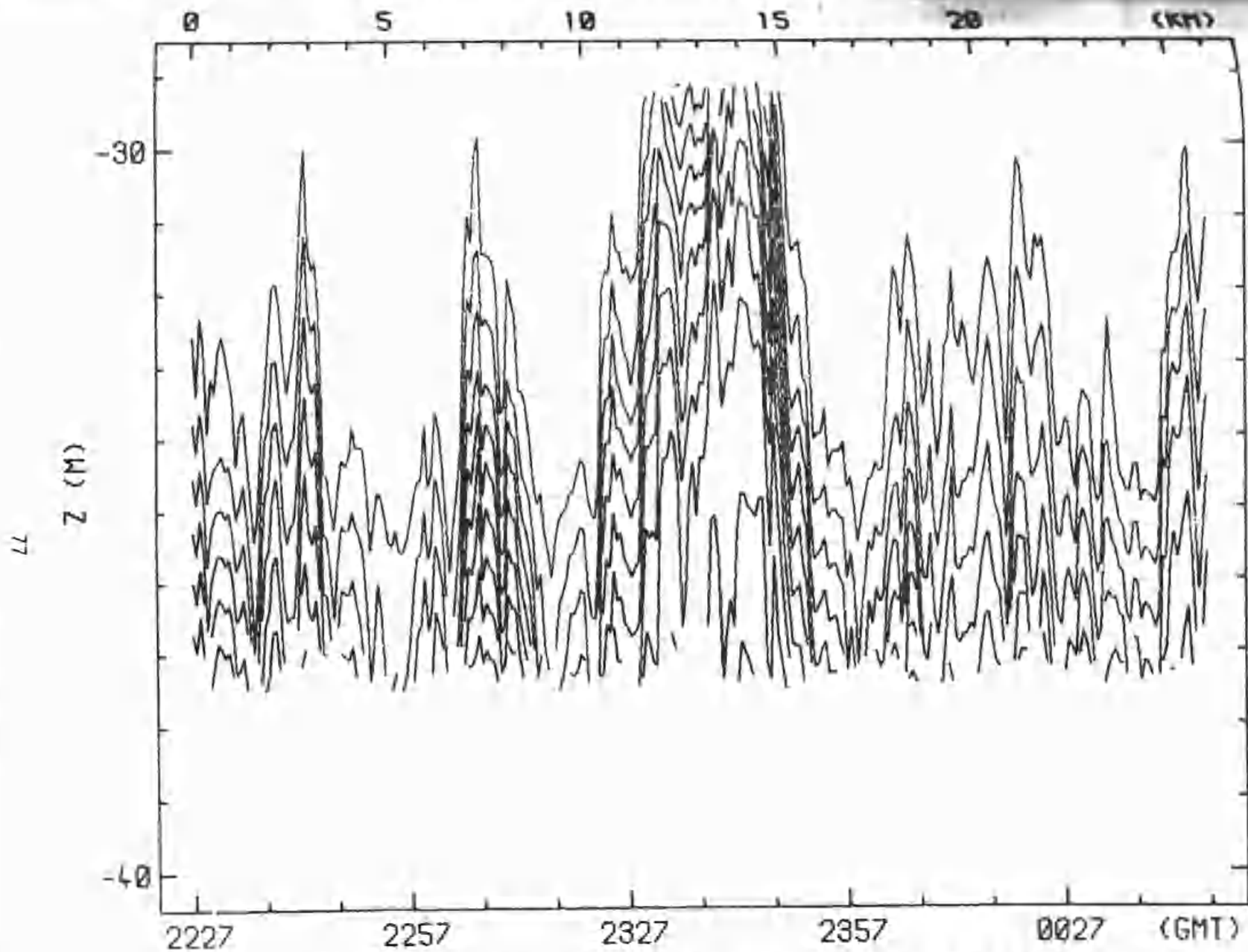


RUN 19 3 SEP 77 ISOTHERMS VS TIME/DISTANCE
T = 7.5 TO 12.0 DEG C IN 0.5 DEG INCREMENTS

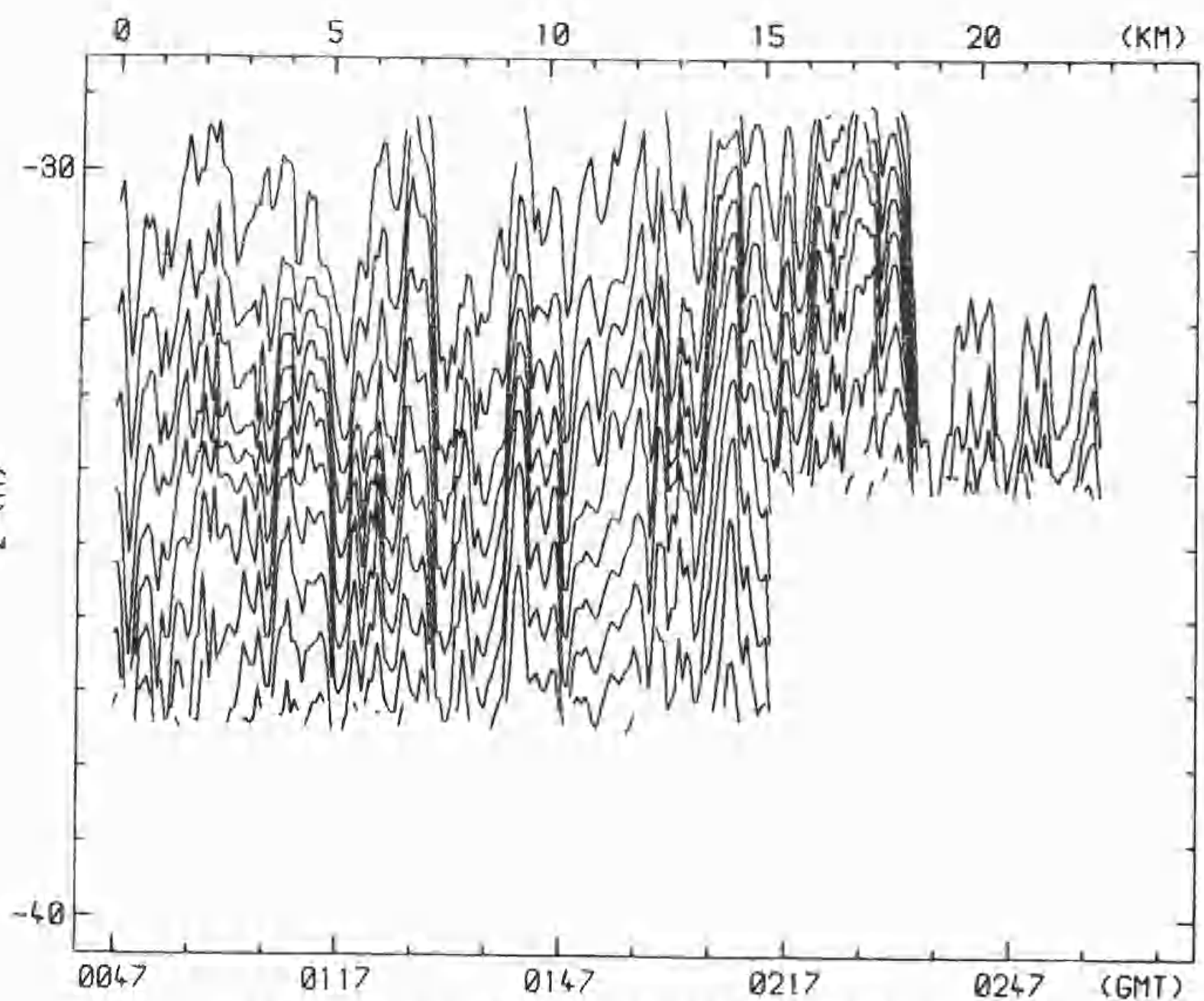


RUN 20 3 SEP 77 ISOTHERMS VS TIME/DISTANCE

T = 7.0 TO 12.0 DEG IN 0.1 DEG INCREMENTS

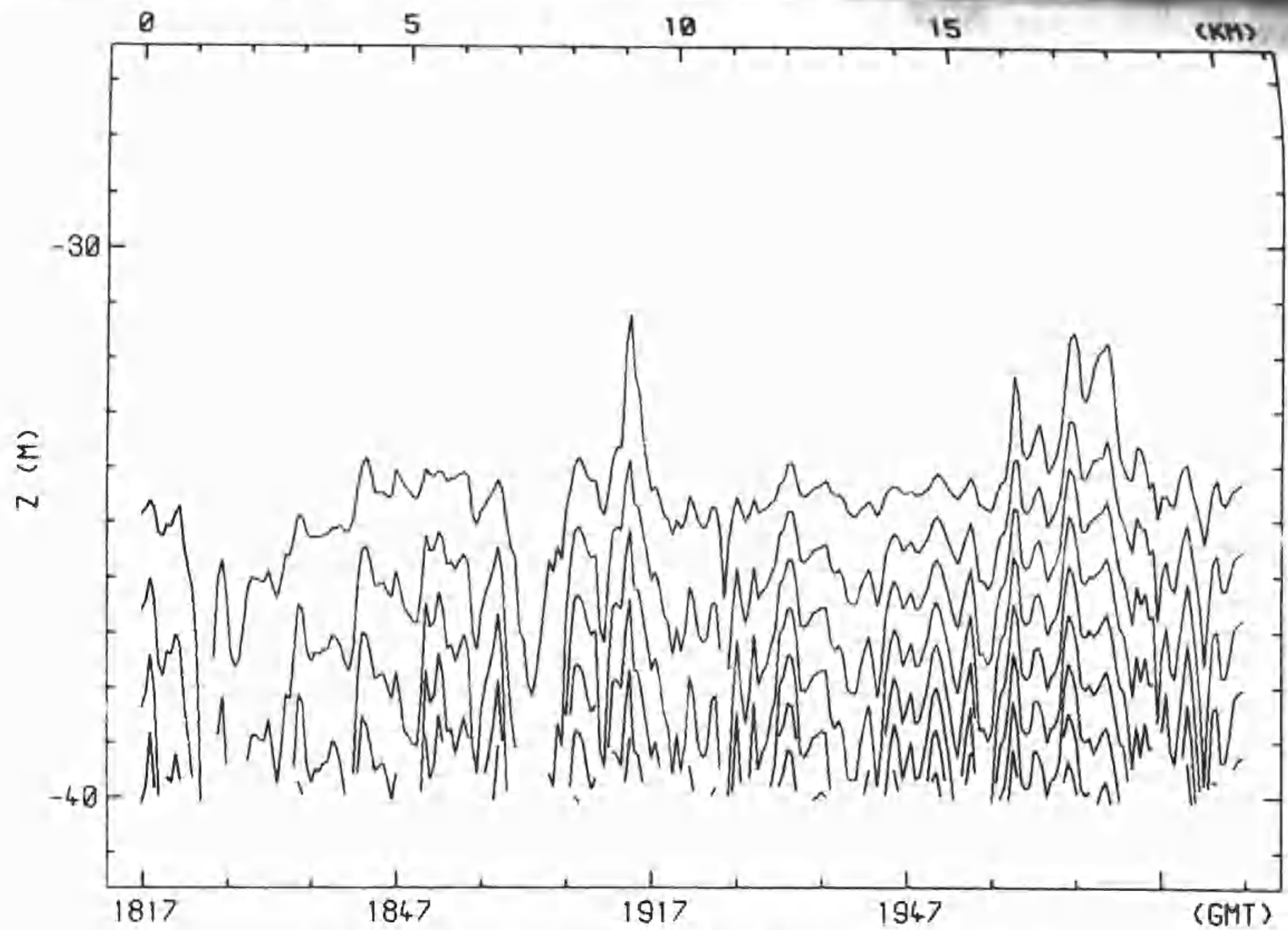


RUN 21 3 SEP 77 ISOTHERMS VS TIME/DISTANCE
T = 7.0 TO 12.0 DEG C IN 0.5 DEG INCREMENTS

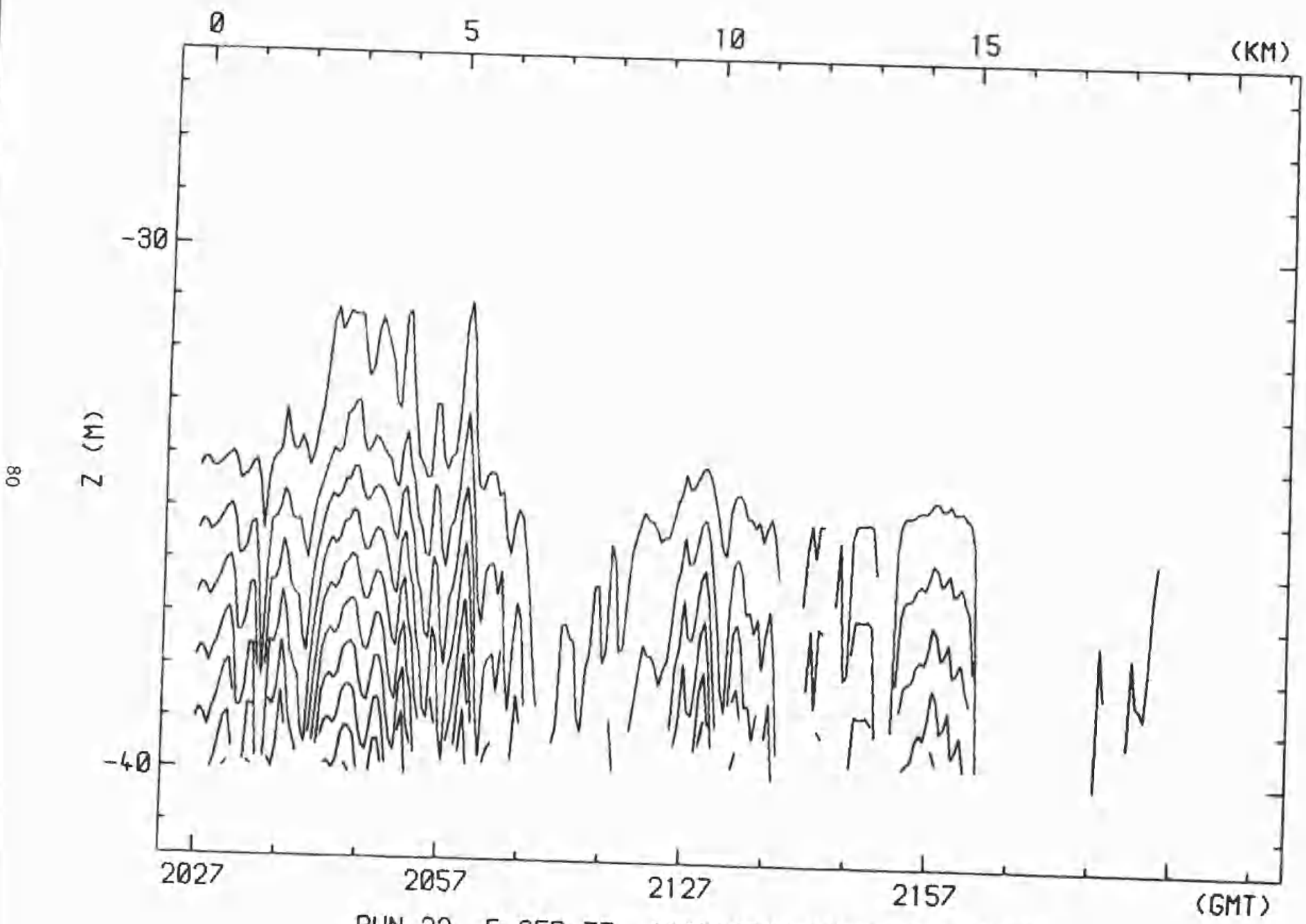


RUN 21 4 SEP 77 ISOTHERMS VS TIME/DISTANCE
T = 6.5 TO 12.0 DEG C IN 0.5 DEG INCREMENTS

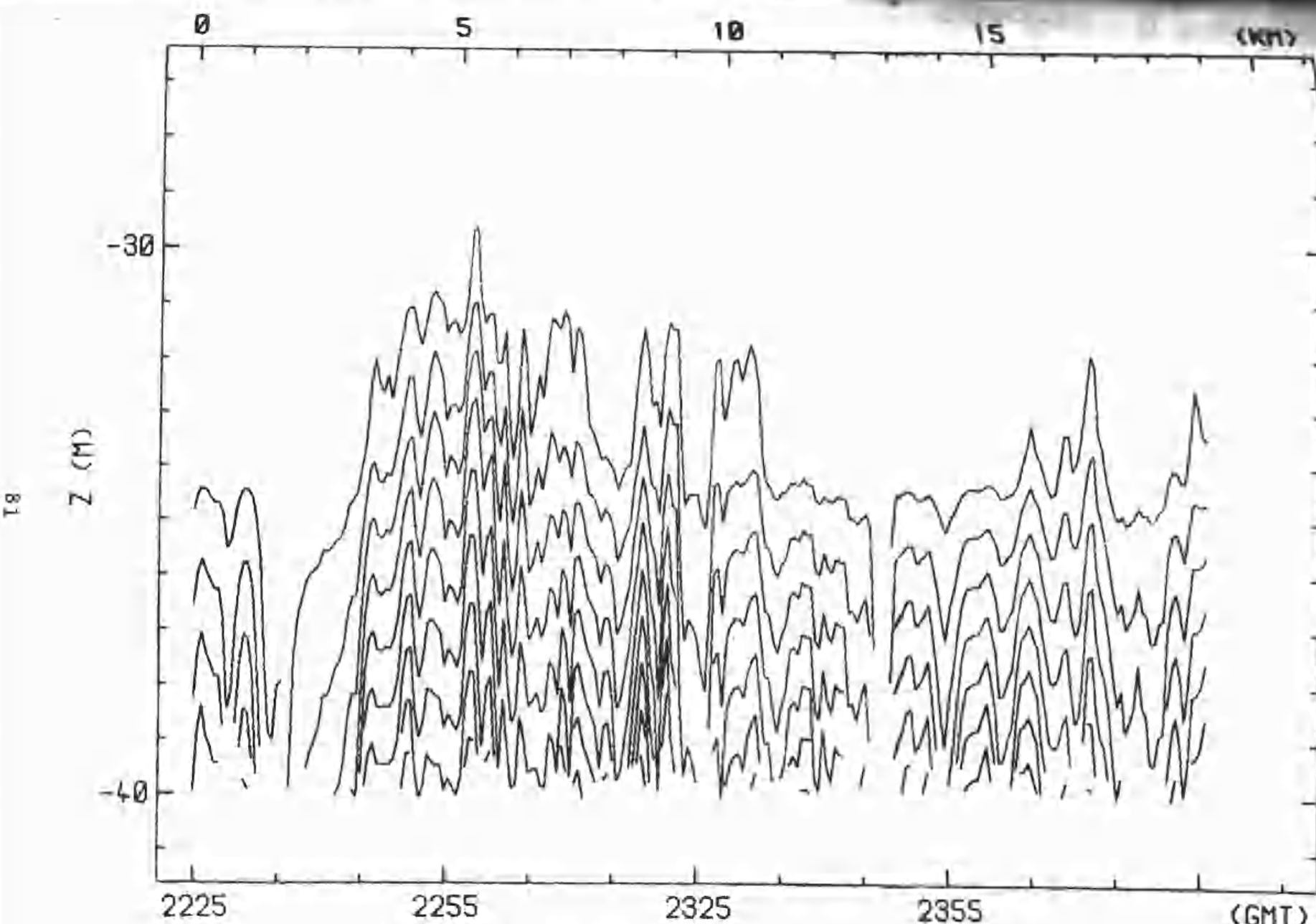
T = 8.5 TO 12.0 DEG C IN 0.5 DEG INCREMENTS



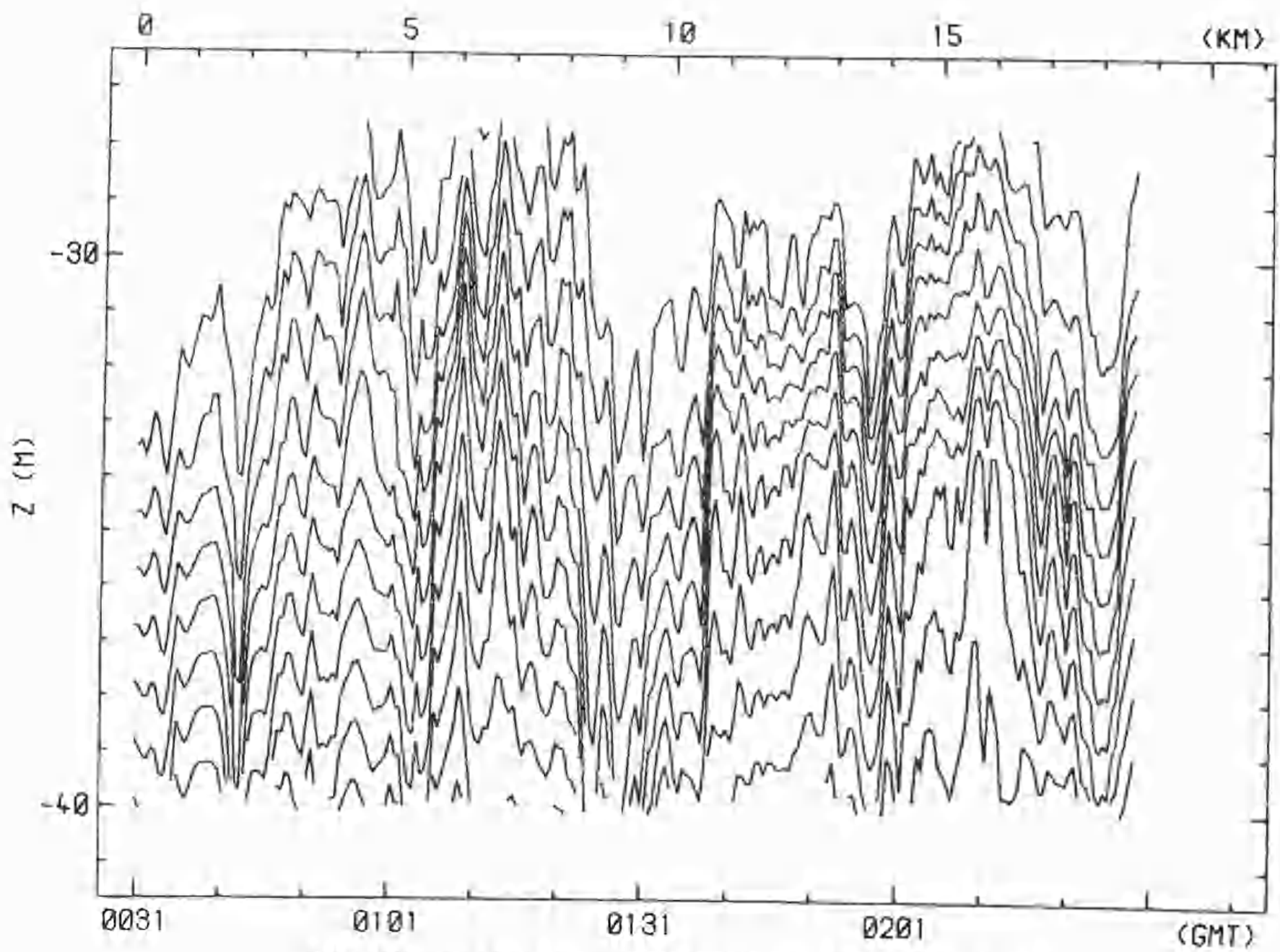
RUN 22 5 SEP 77 ISOTHERMS VS TIME/DISTANCE
T = 8.0 TO 12.0 DEG C IN 0.5 DEG INCREMENTS



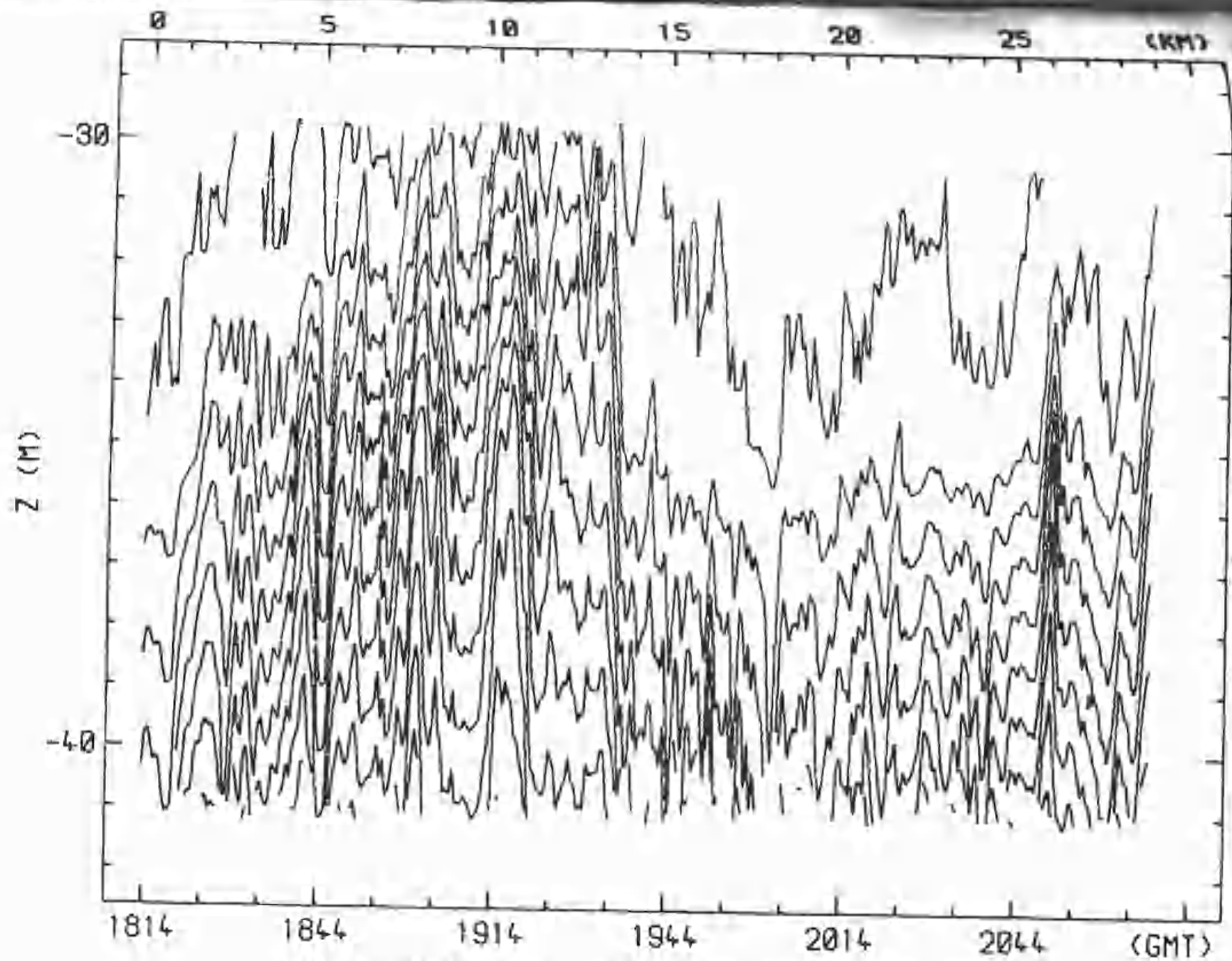
RUN 22 5 SEP 77 ISOTHERMS VS TIME/DISTANCE



RUN 22 5 SEP 77 ISOTHERMS VS TIME/DISTANCE
T = 8.0 TO 12.0 DEG C IN 0.5 DEG INCREMENTS



RUN 23 6 SEP 77 ISOTHERMS VS TIME/DISTANCE
T = 6.5 TO 12.0 DEG C IN 0.5 DEG INCREMENTS

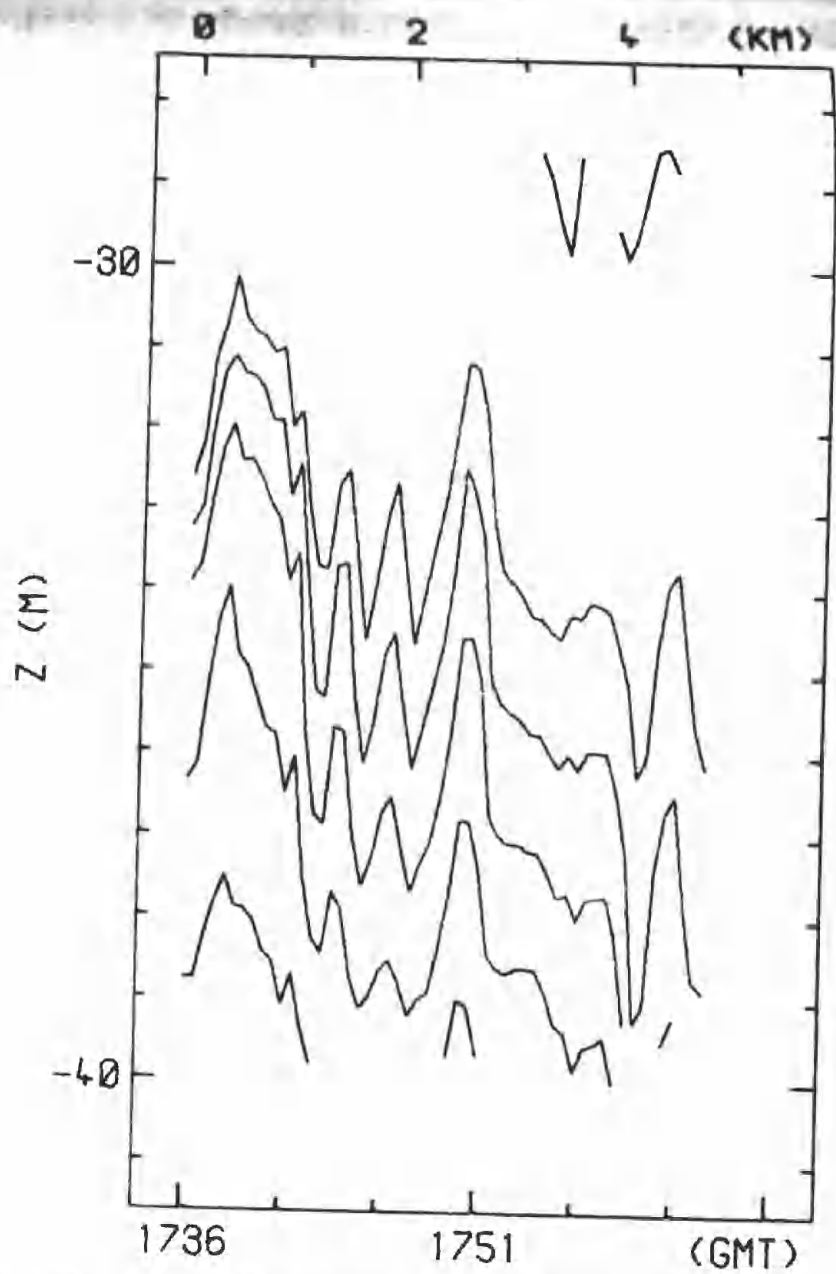


RUN 24 8 SEP 77 ISOTHERMS VS TIME/DISTANCE
T = 6.5 TO 12.5 DEG C IN 0.5 DEG INCREMENTS

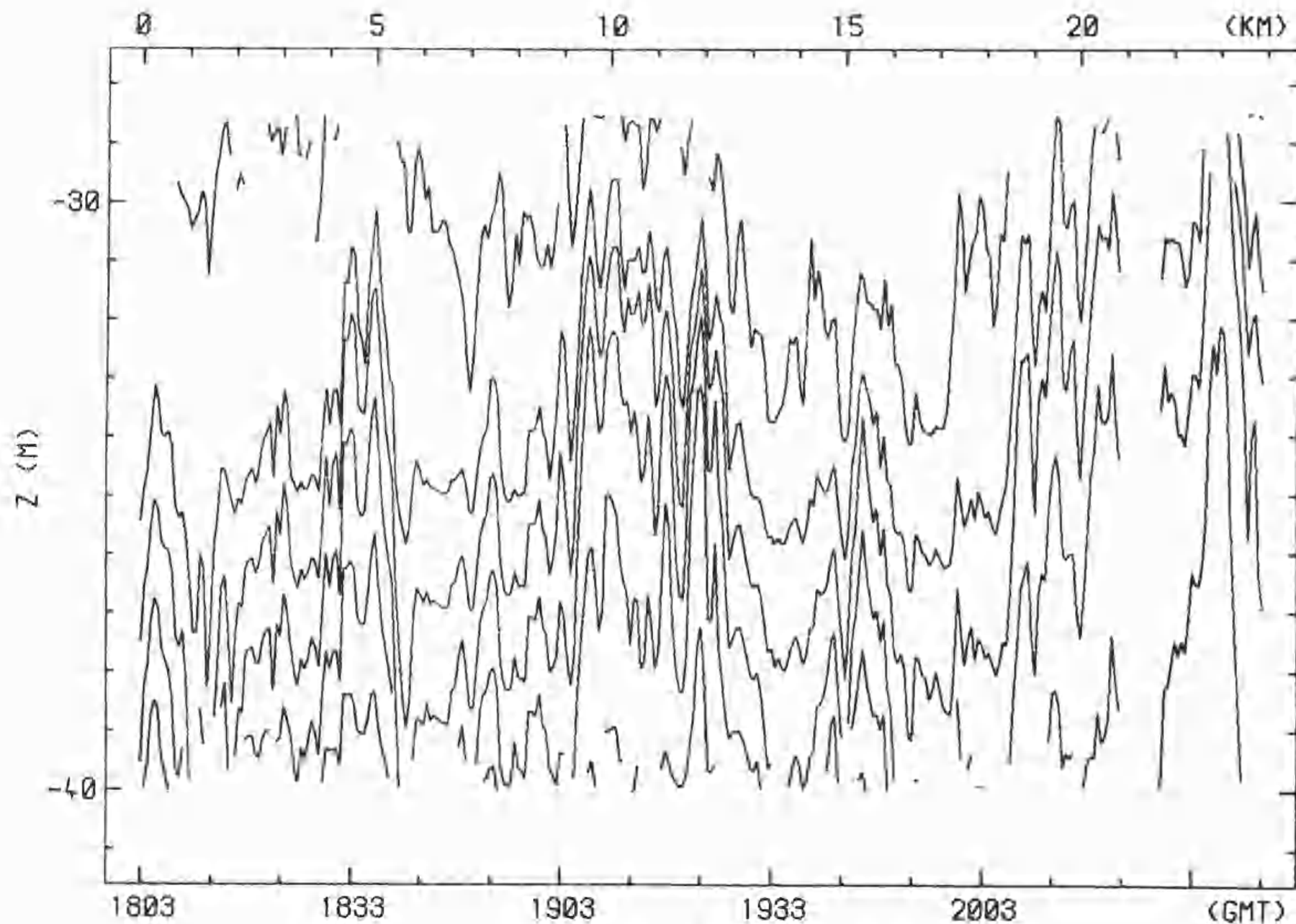
APPENDIX D

Isotherm Cross-sections, 1.0° Spacing

Isotherm depths, interpolated linearly from the temperature observations shown in Appendix B are plotted on the following pages for selected runs.



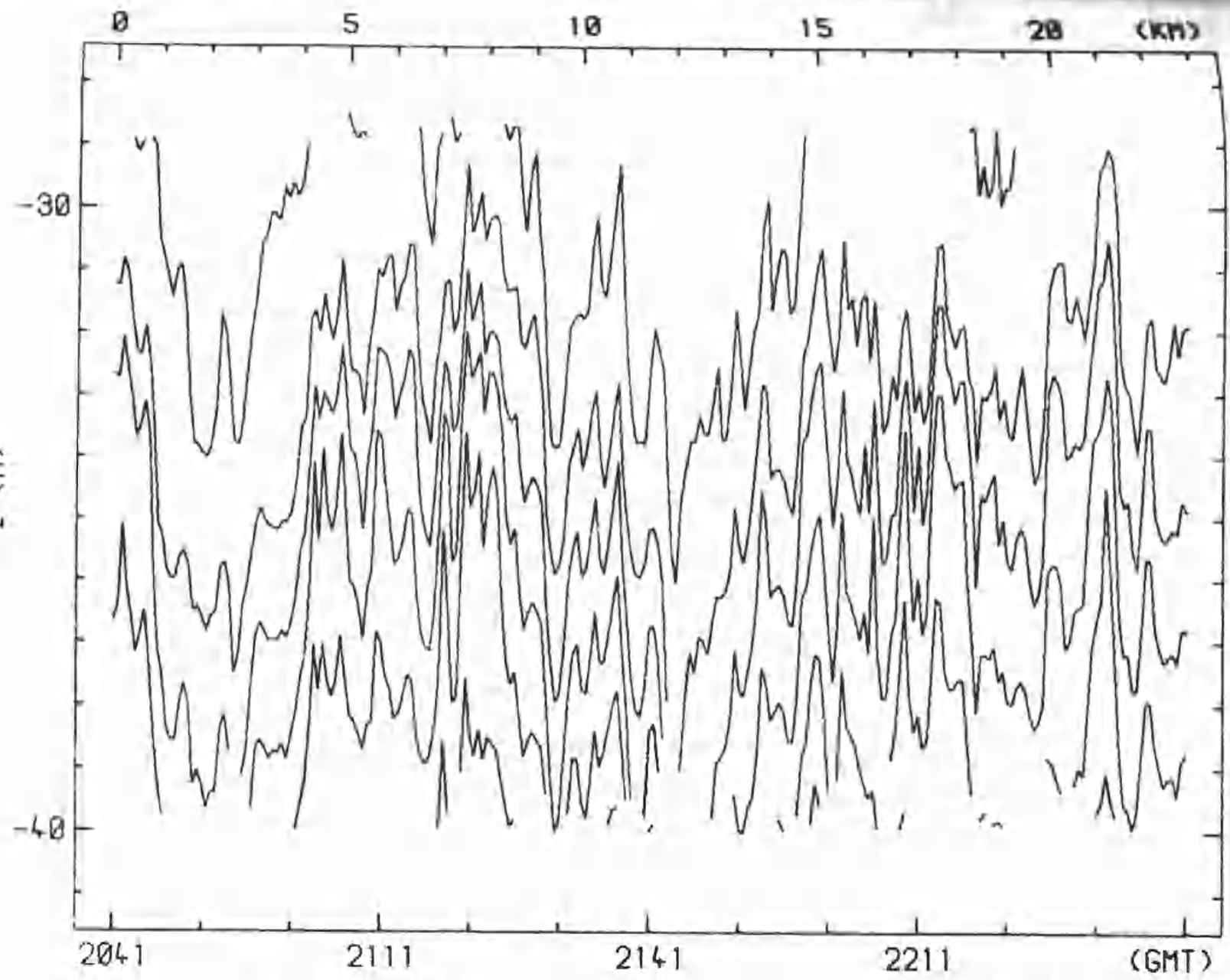
RUN 13 30 AUG 77 ISOTHERMS VS TIME/DISTANCE
T = 7.0 TO 12.0 DEG C IN 1.0 DEG INCREMENTS



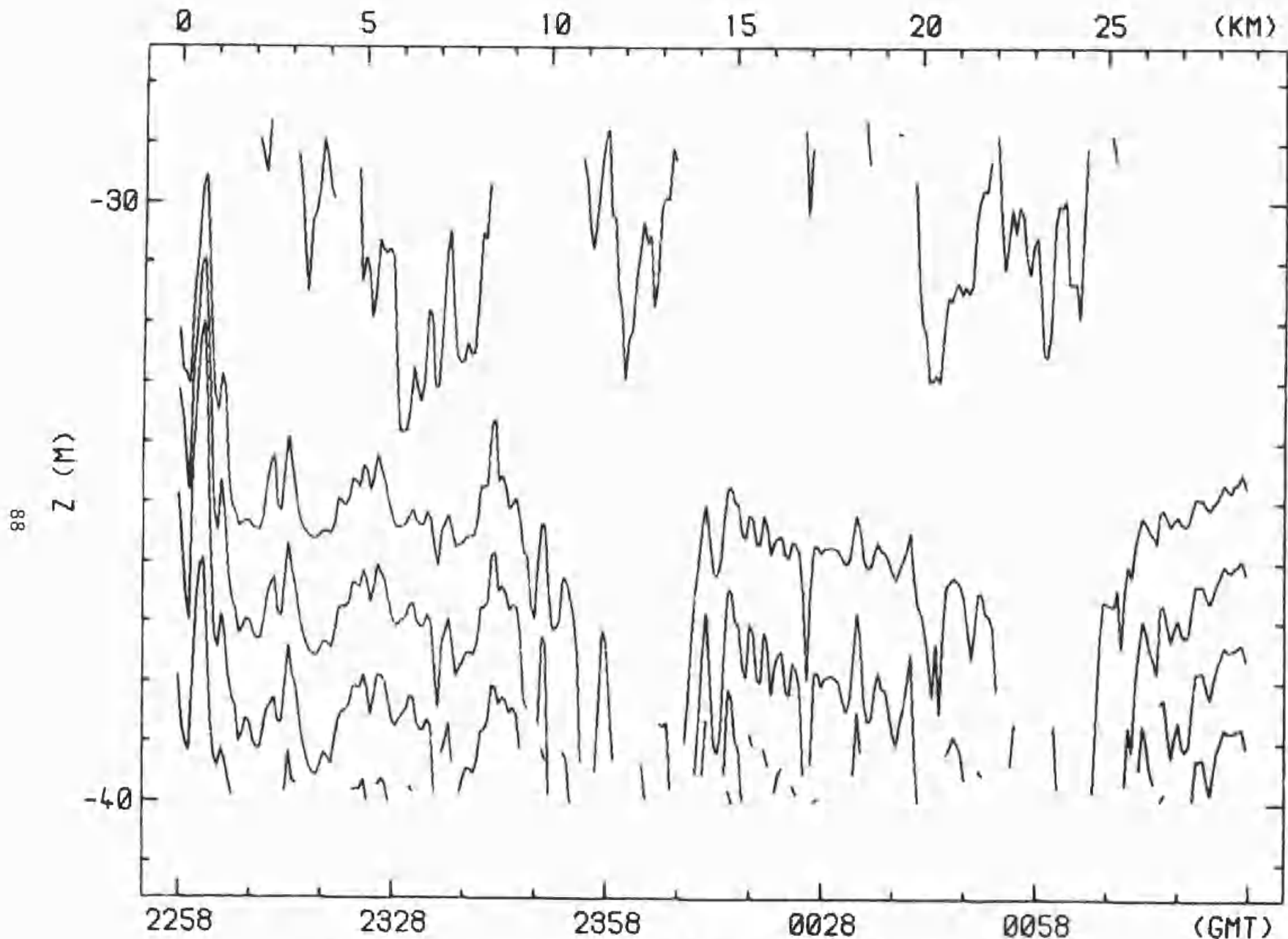
RUNS 13-14 30 AUG 77 ISOTHERMS VS TIME/DISTANCE

T = 7.0 TO 12.0 DEG C IN 1.0 DEG INCREMENTS

87

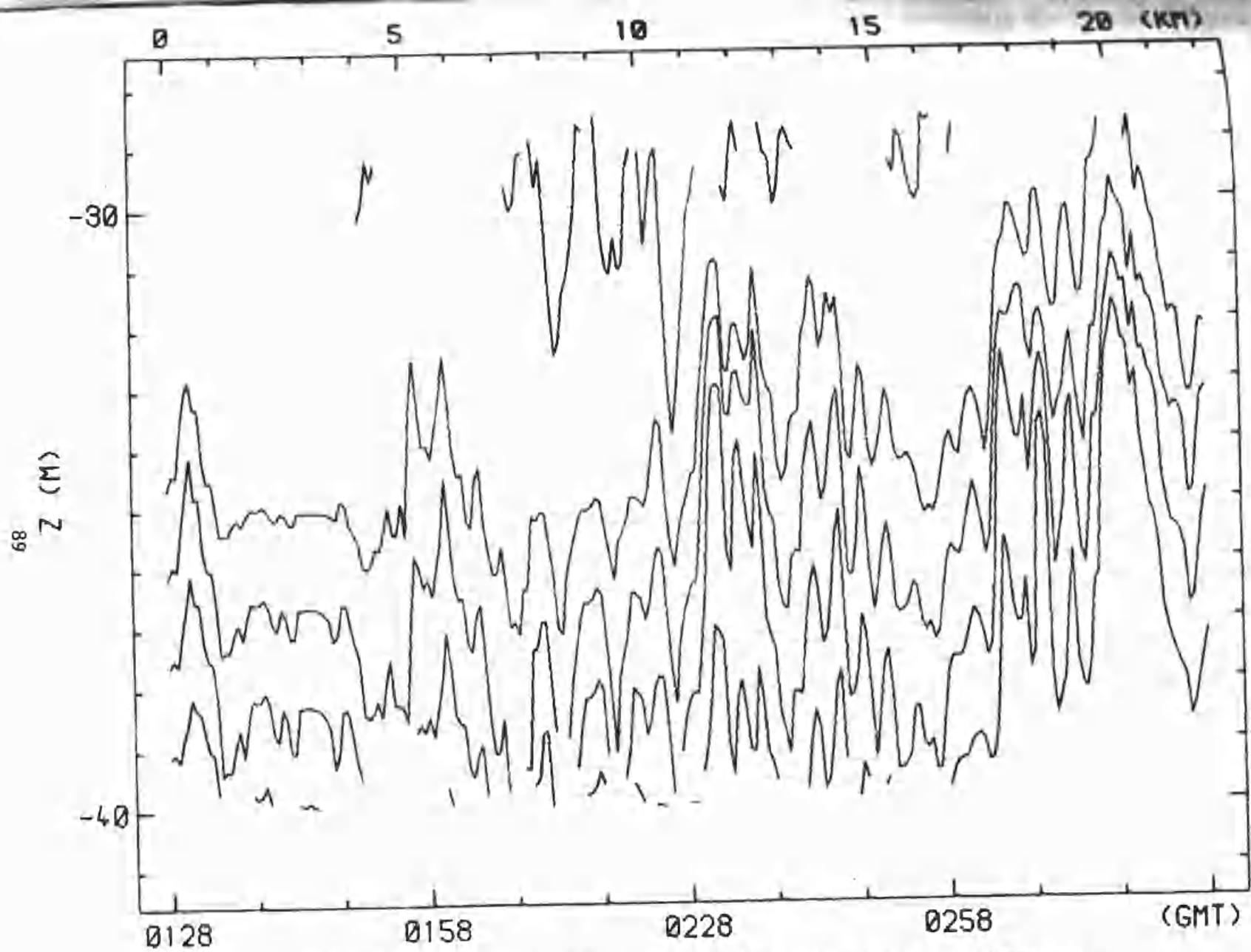


RUN 14 30 AUG 77 ISOTHERMS VS TIME/DISTANCE
T = 7.0 TO 12.0 DEG C IN 1.0 DEG INCREMENTS

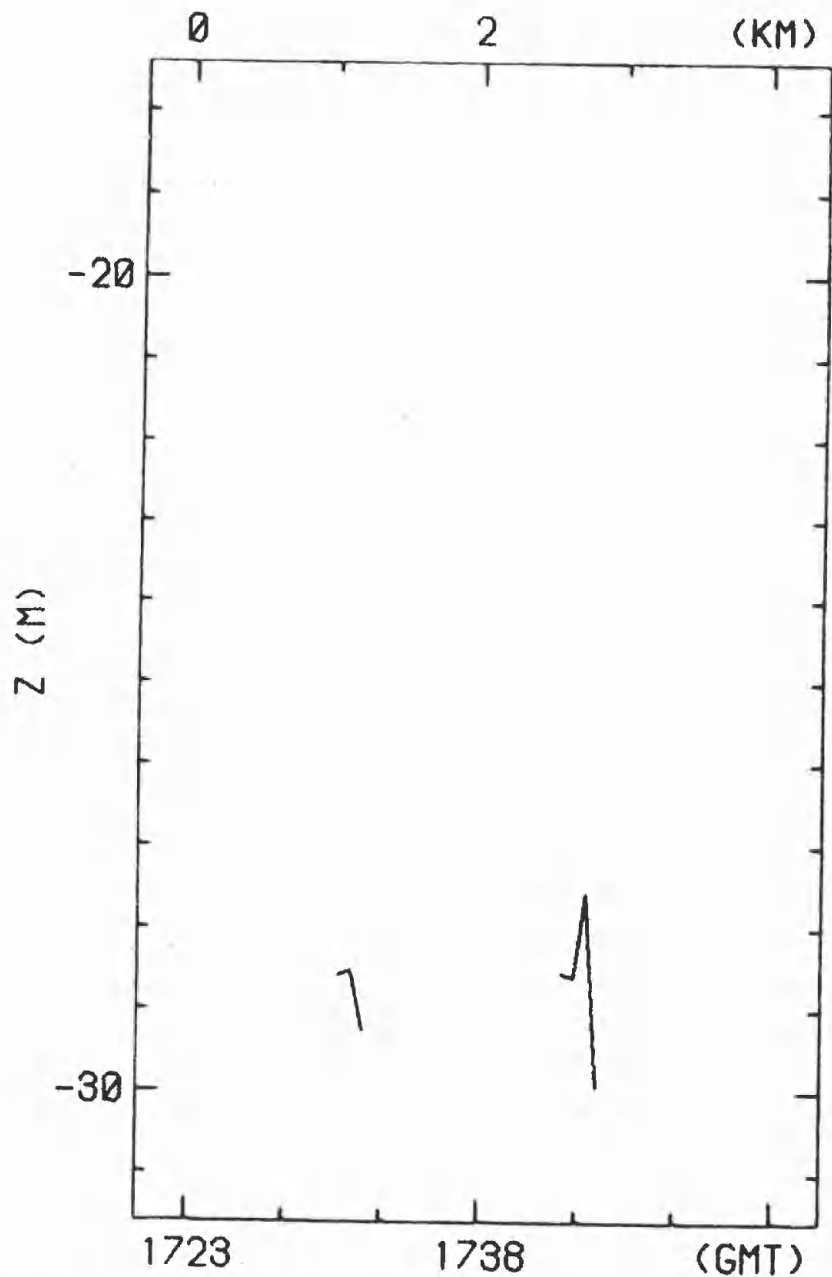


RUN 15 30 AUG 77 ISOTHERMS VS TIME/DISTANCE

T = 8.0 TO 12.0 DEG C IN 1.0 DEG INCREMENTS

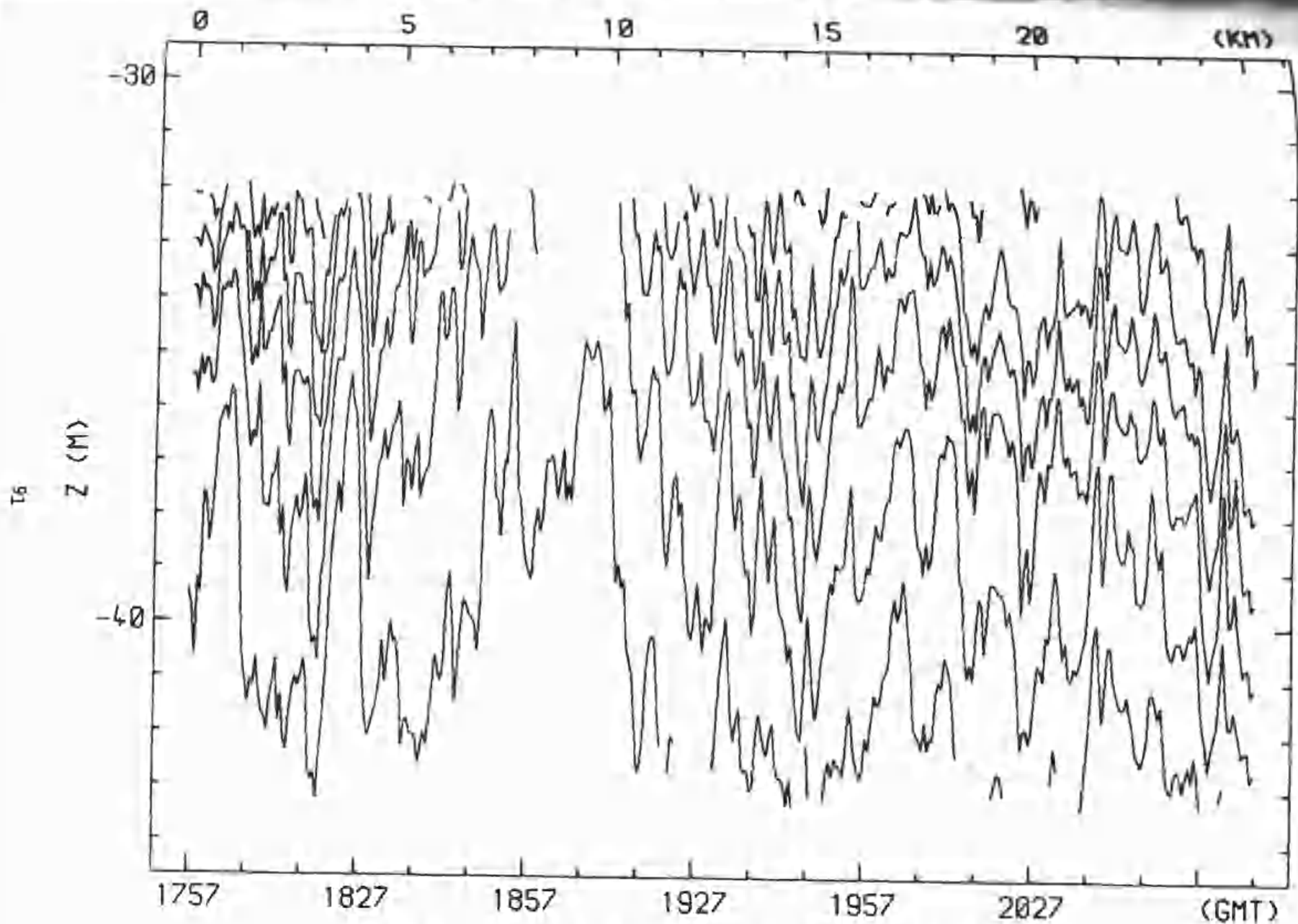


RUN 15 31 AUG 77 ISOTHERMS VS TIME/DISTANCE
T = 8.0 TO 12.0 DEG C IN 1.0 DEG INCREMENTS

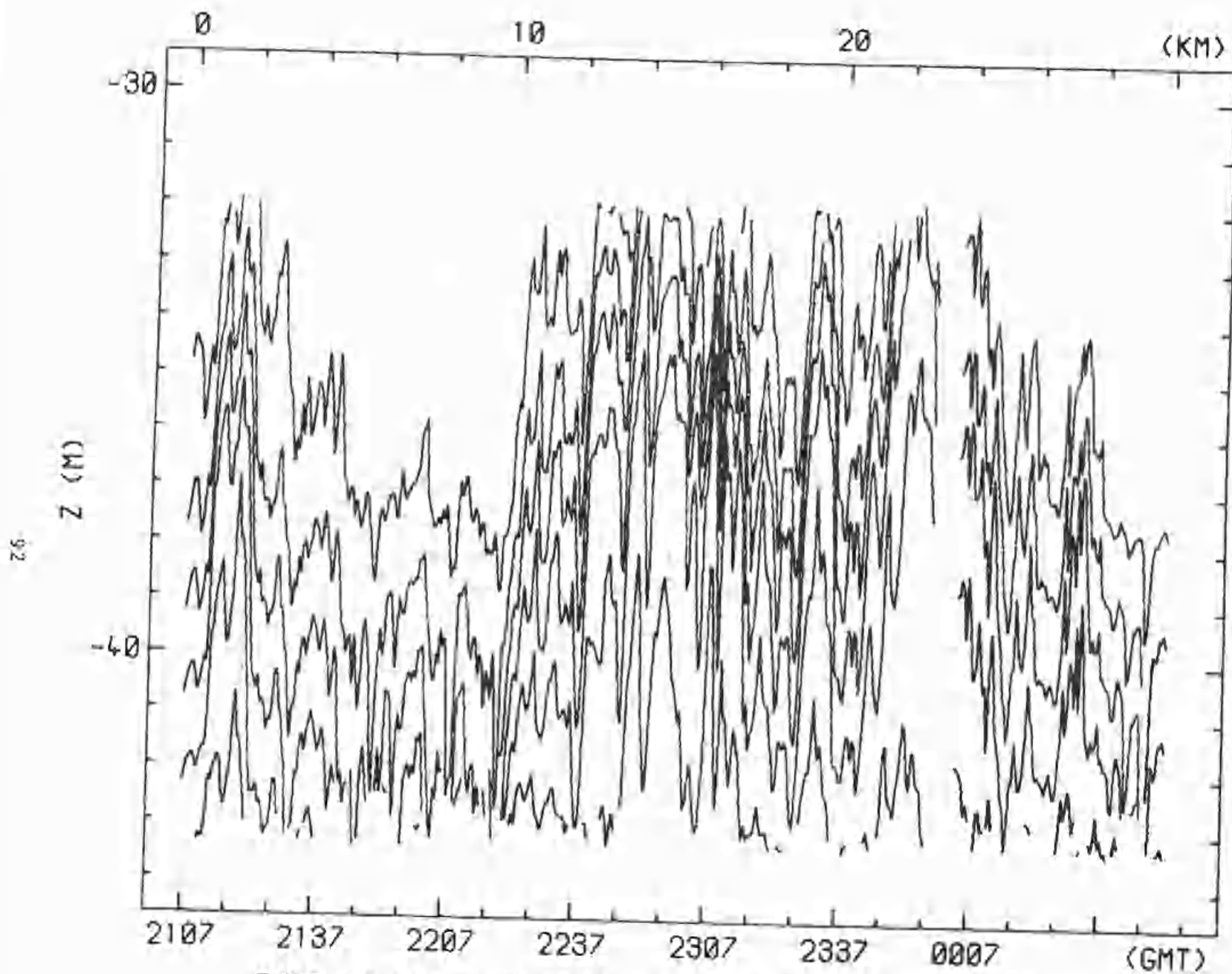


RUN 16 1 SEP 77 ISOTHERM VS TIME/DISTANCE

T = 12.0 DEG C



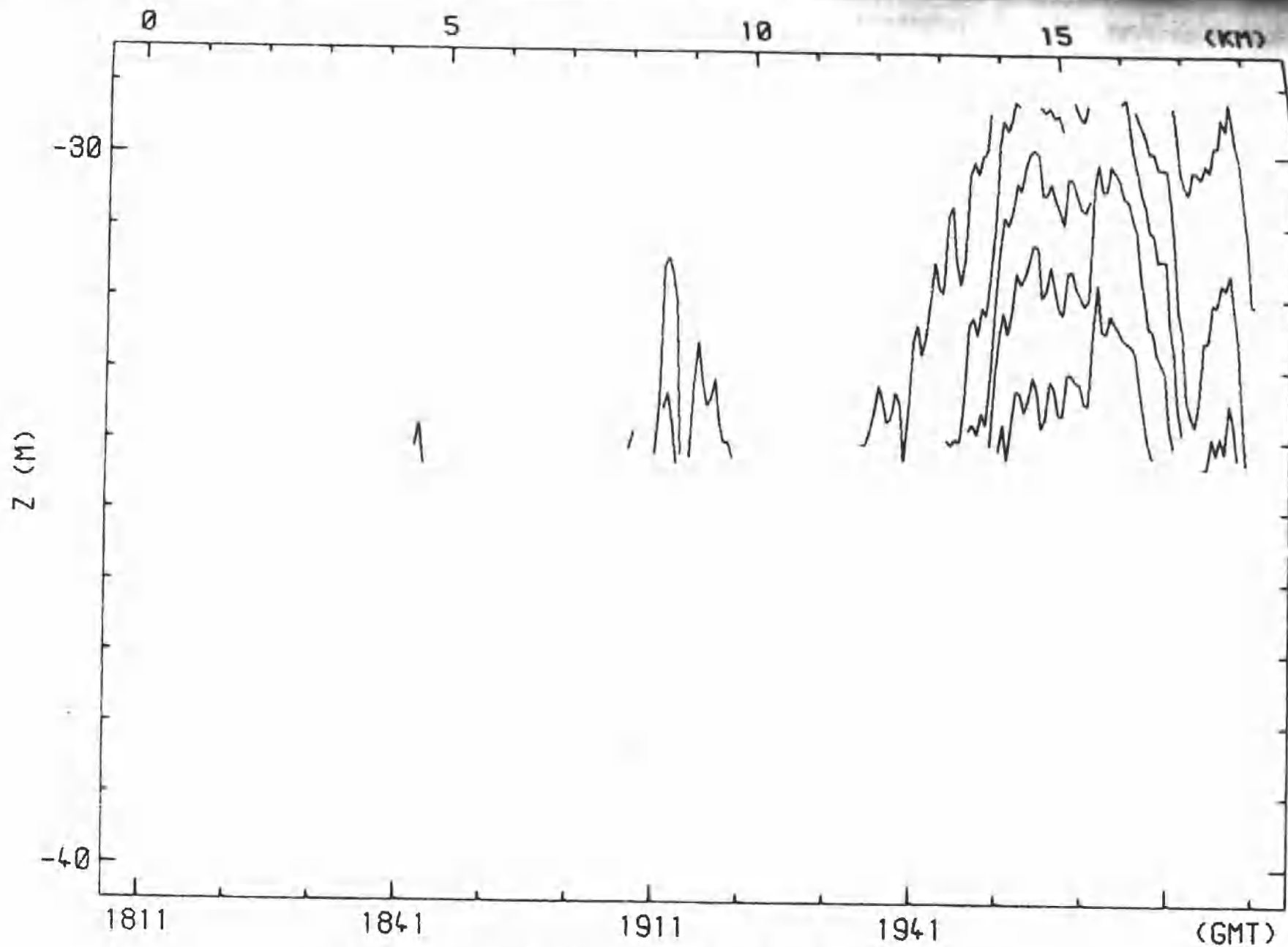
RUN 17 1 SEP 77 ISOTHERMS VS TIME/DISTANCE
T = 7.0 TO 12.0 DEG C IN 1.0 DEG INCREMENTS



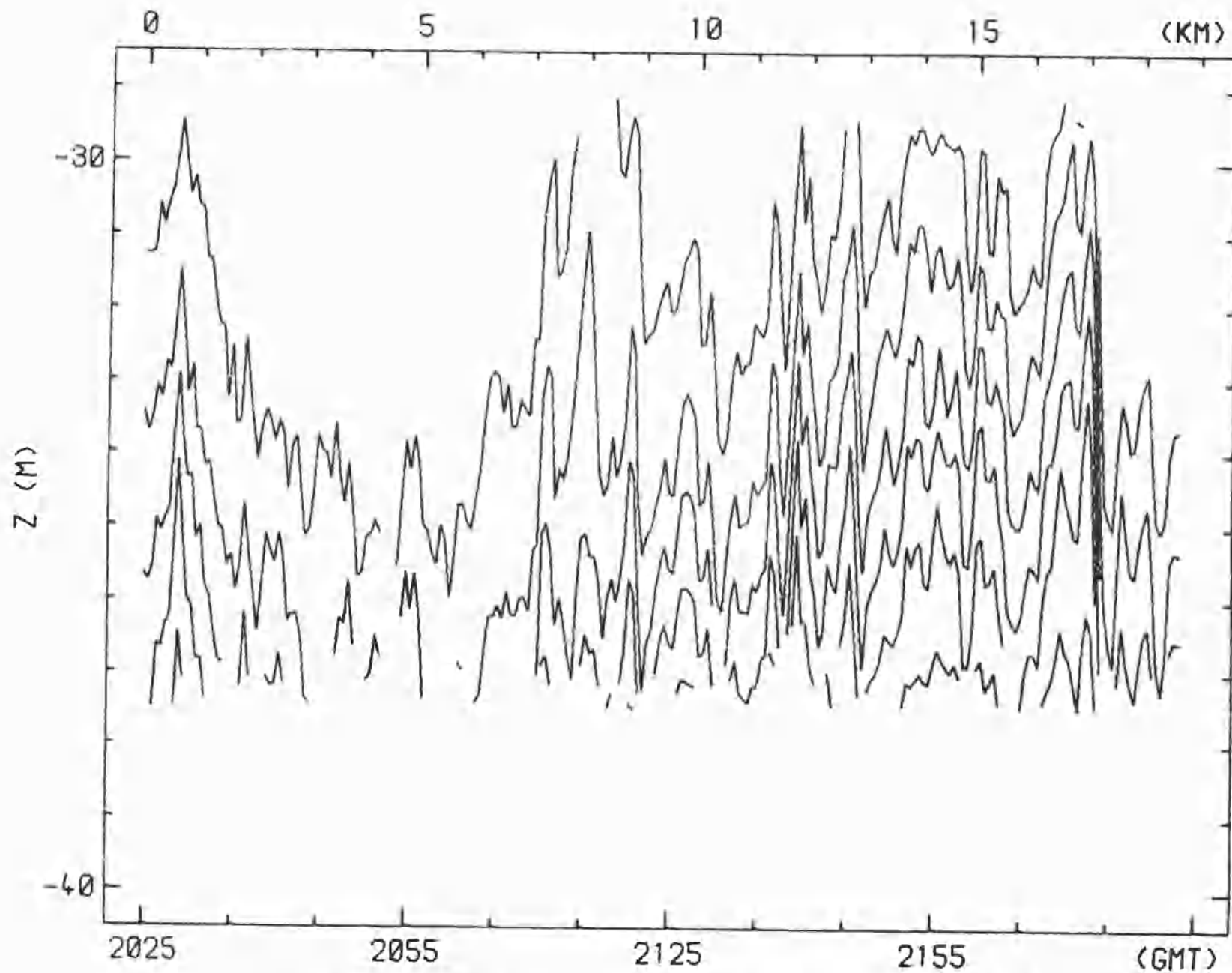
RUNS 17-18 1 SEP 77 ISOTHERMS VS TIME/DISTANCE

T = 7.0 TO 12.0 DEG C IN 1.0 DEG C STEPS

93



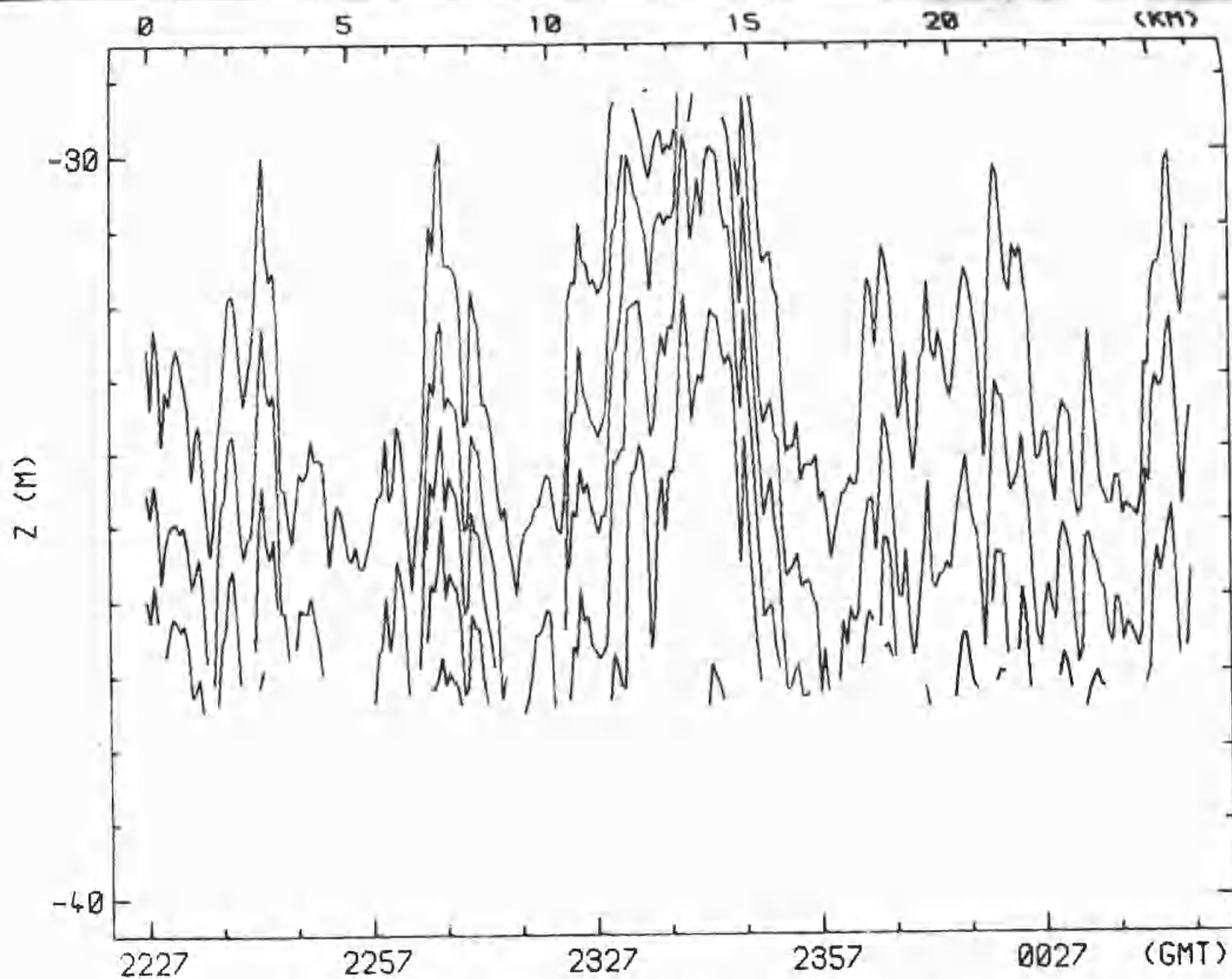
RUN 19 3 SEP 77 ISOTHERMS VS TIME/DISTANCE
T = 8.0 TO 12.0 DEG C IN 1.0 DEG INCREMENTS



RUN 20 3 SEP 77 ISOTHERMS VS TIME/DISTANCE
T = 7.0 TO 12.0 DEG C IN 1.0 DEG INCREMENTS

76

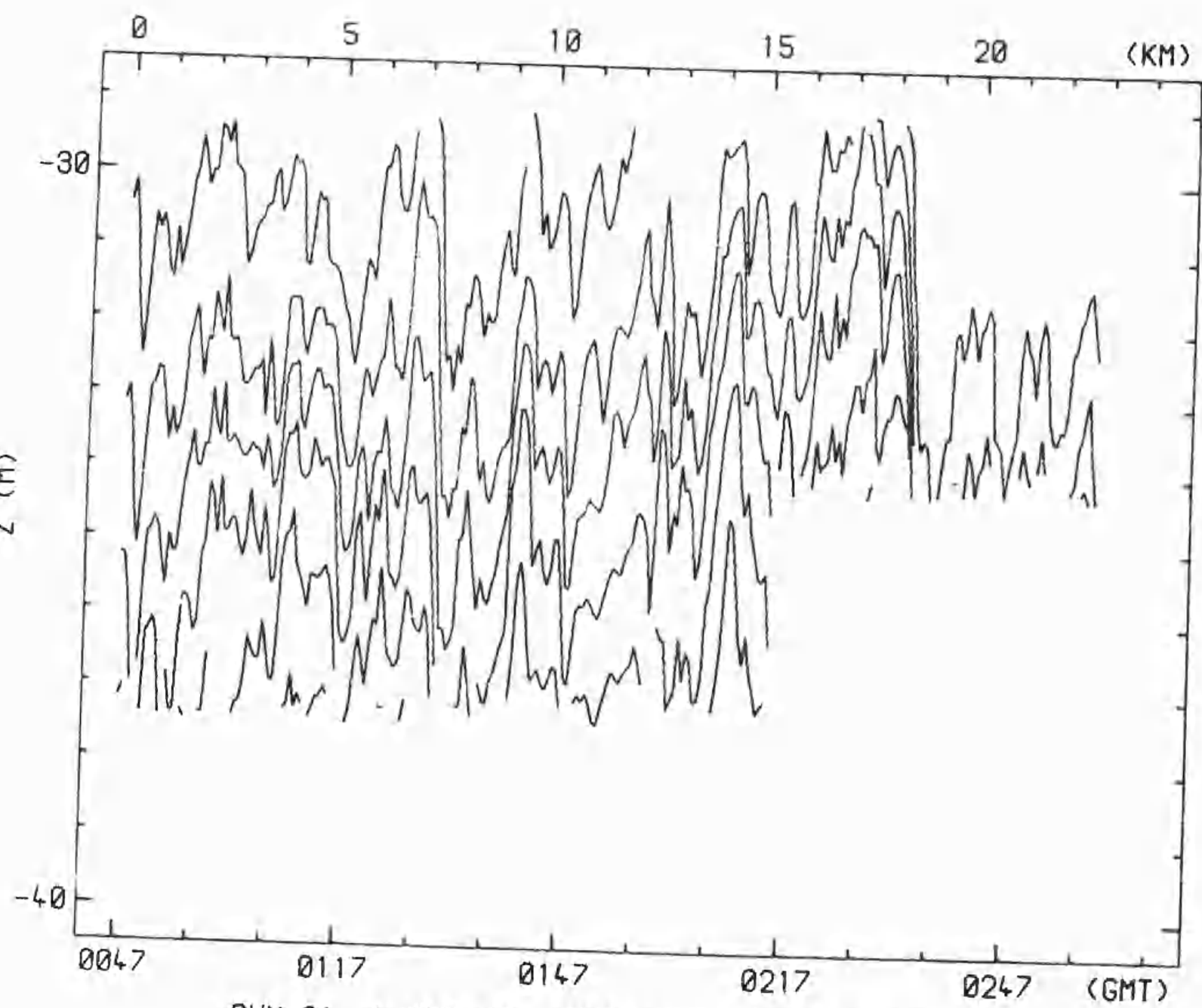
96



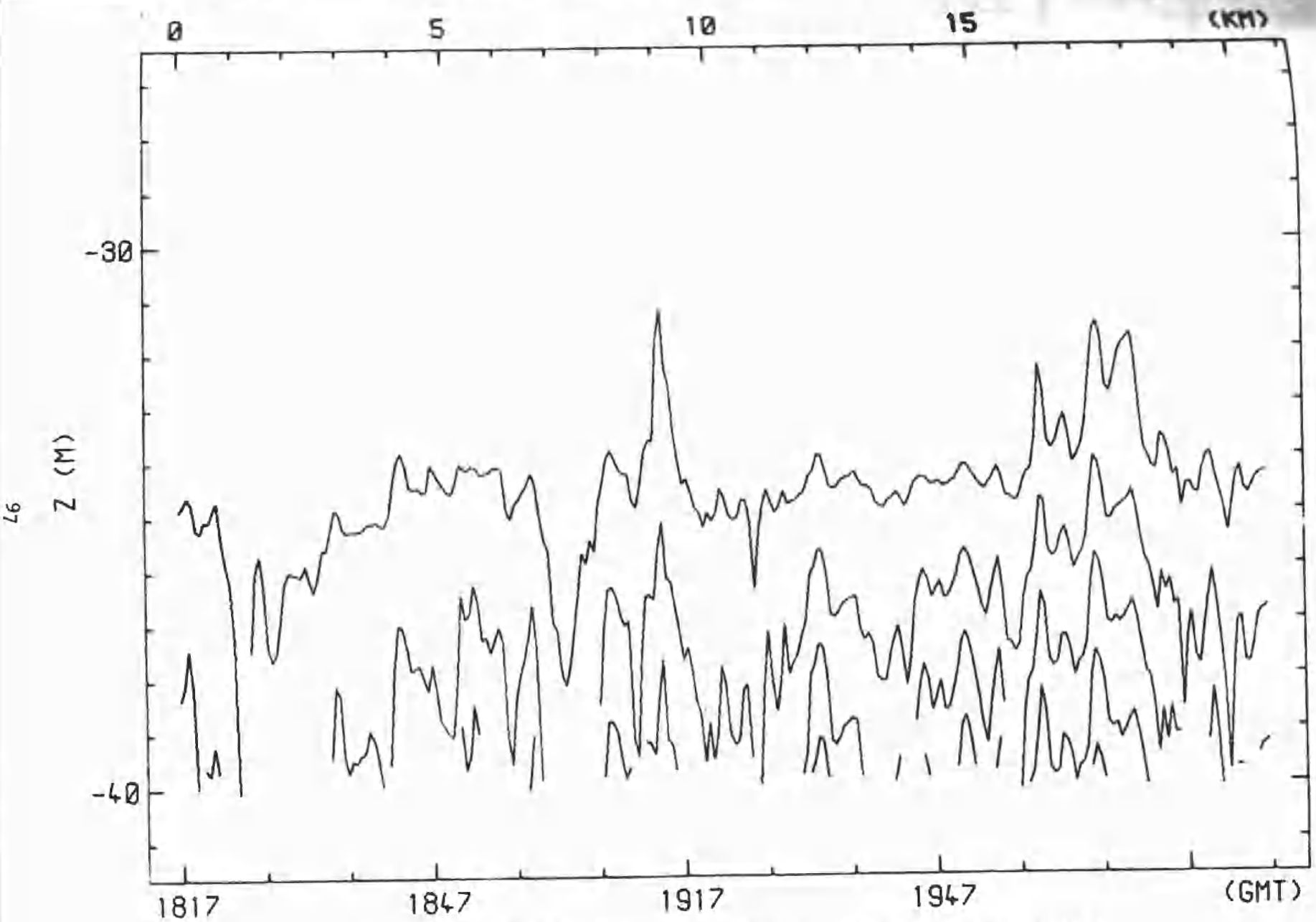
RUN 21 3 SEP 77 ISOTHERMS VS TIME/DISTANCE

T = 7.0 TO 12.0 DEG C IN 1.0 DEG INCREMENTS

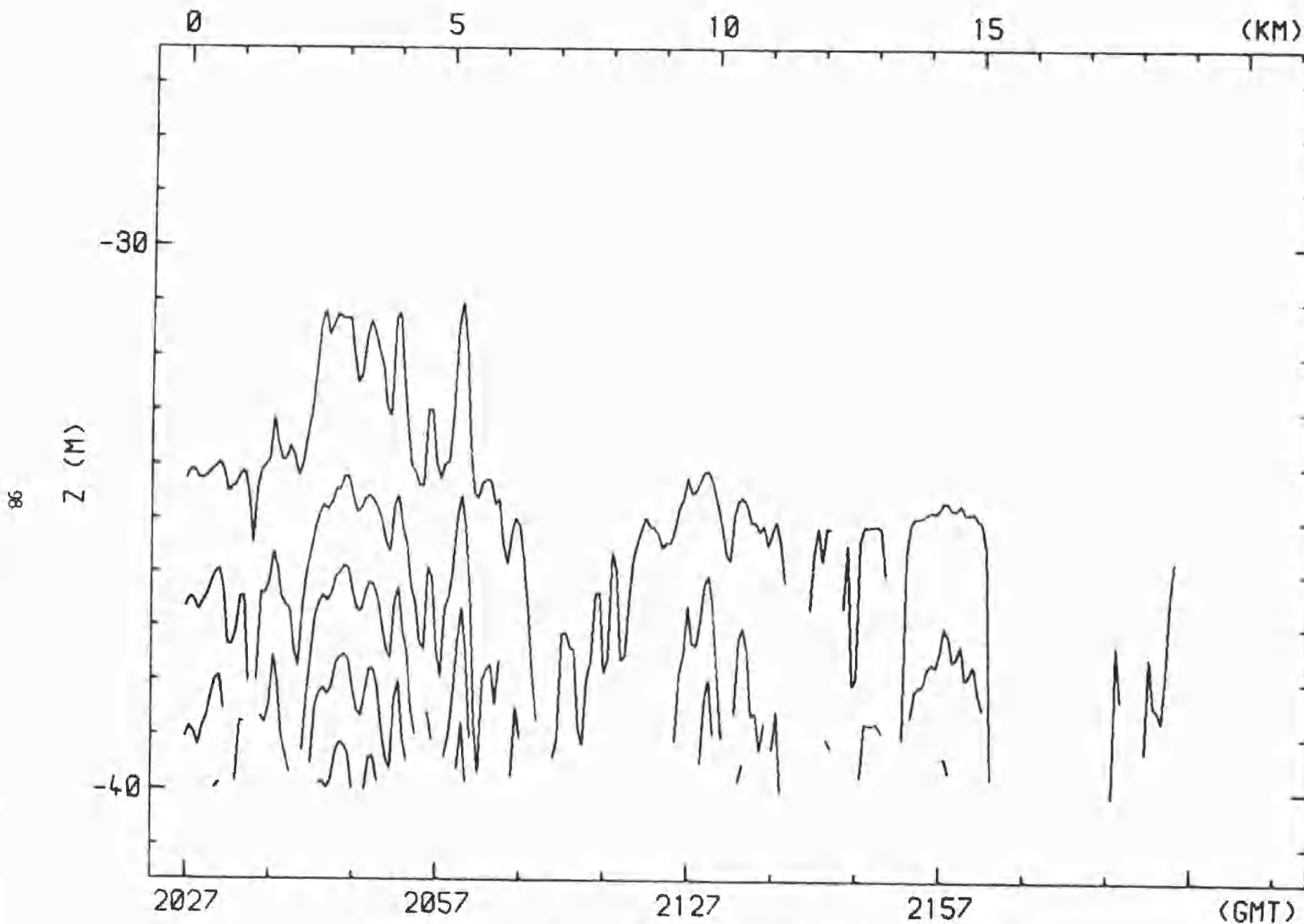
96



RUN 21 4 SEP 77 ISOTHERMS VS TIME/DISTANCE
T = 7.0 TO 12.0 DEG C IN 1.0 DEG INCREMENTS

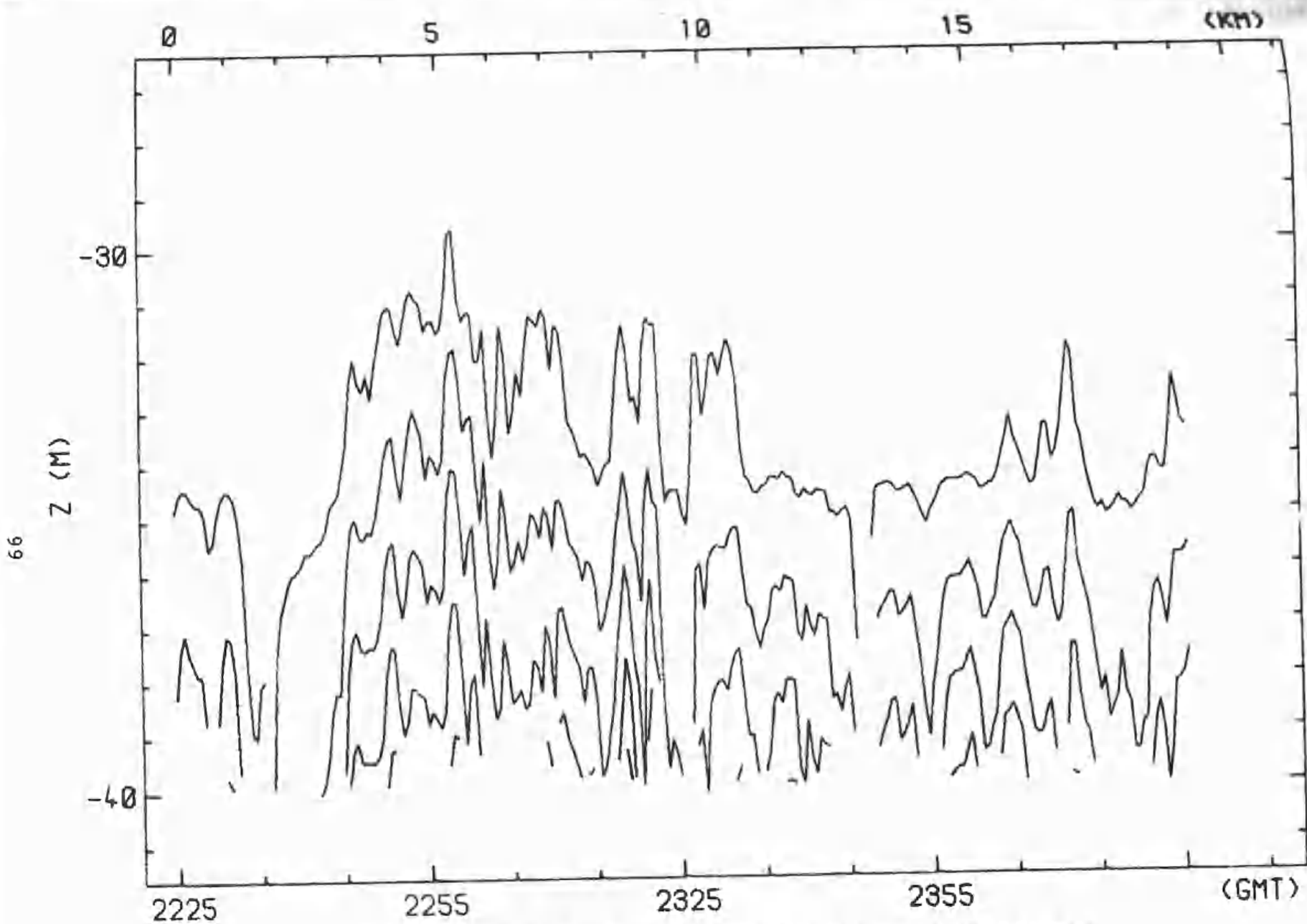


RUN 22 5 SEP 77 ISOTHERMS VS TIME/DISTANCE
T = 8.0 TO 12.0 DEG C IN 1.0 DEG INCREMENTS

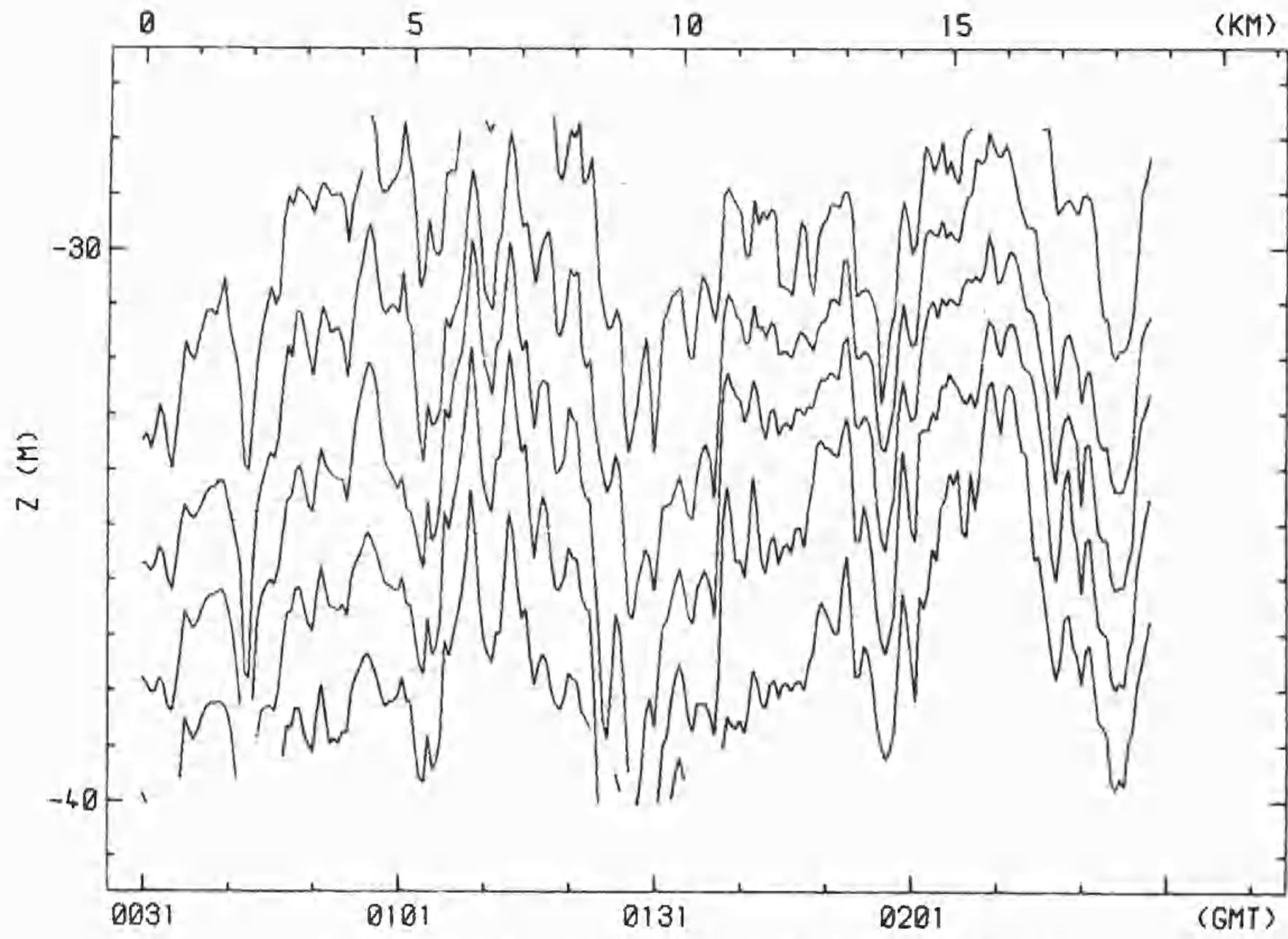


RUN 22 5 SEP 77 ISOTHERMS VS TIME/DISTANCE

T = 2.0 TO 12.0 DEG C IN 1.0 DEG INCREMENT

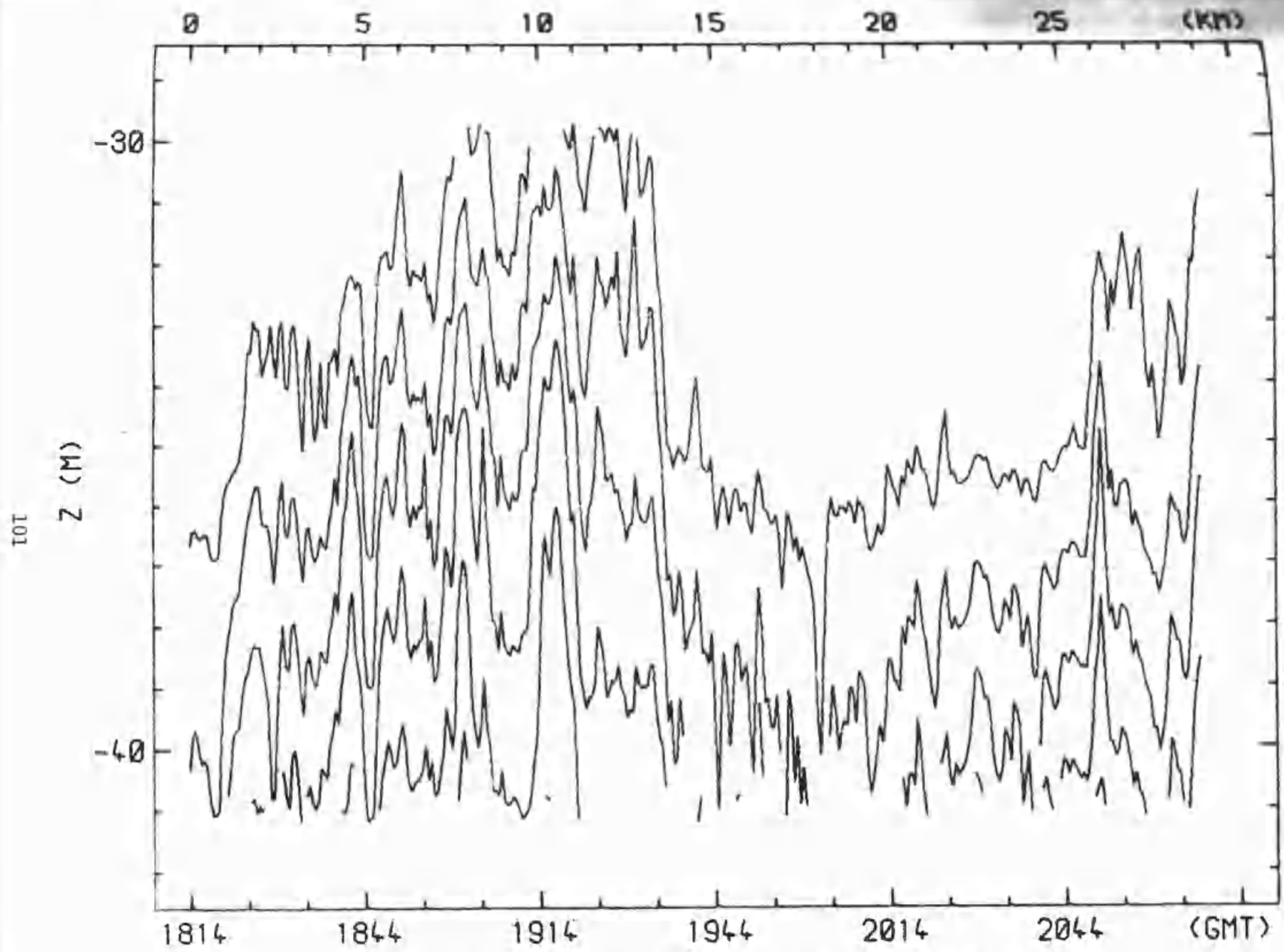


RUN 22 5 SEP 77 ISOTHERMS VS TIME/DISTANCE
T = 8.0 TO 12.0 DEG C IN 1.0 DEG INCREMENTS



RUN 23 6 SEP 77 ISOTHERMS VS TIME/DISTANCE

8.0 TO 13.0 DEG C IN 0.5 DEG INCREMENTS



RUN 24 8 SEP 77 ISOTHERMS VS TIME/DISTANCE
T = 7.0 TO 12.0 DEG C IN 1.0 DEG INCREMENTS