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Preliminary report on currents in the N. Rockall Trough.

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Institute of Oceanographic Sciences,
Wormley.

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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Preliminary report on currents in the N. Rockall Trough.

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Currents in the N. Rockall Trough

Preliminary Report

Introduction

This is a preliminary report of some current meter measurements made by the Institute of Oceanographic Sciences in the Northern Rockall trough during the Joint Air-Sea Interaction Experiment (JASIN) in the summer of 1978. The work was sponsored by the Department of Energy. The current measurements which are the subject of this report formed part of a project to study the deep circulation of the Rockall Trough and its response to atmospheric forcing. The scientific development of the programme is outlined in Appendix 1.

The moorings.

Five subsurface current meter moorings carrying a total of 19 Aanderaa recording current meters were set at the positions I1 to I5 shown in fig. 1. The buoys were in place from mid-July to early September. The details of mooring positions, times of deployment and recovery and water depths are contained in Table 1. Figure 2 is a schematic diagram of the deepest of the five moorings. All except I1 carried four current meters which were intended to settle at depths close to 200, 600, 1000 and 1500m. Where the depths were shallower than this (I1 and I2) the lowest current meter was omitted or moved to about 20m above the sea bed.

The actual depths attained by the instruments are shown in table 2. The variations from the nominal values are due to inaccuracies in the precut wire lengths and in departures of the actual water depths from those shown on the bathymetric charts. Pressure transducers on the uppermost instrument of some of the moorings showed that the depth variations of the top of the moorings due to current drag were typically less than $\pm$ 10m during the 2 month record and thus depth variations of the deeper instruments were proportionately less.

Individual current meter records are referred to by a number consisting of the IOS mooring number combined with the sequence number of the instrument measured from the top of the mooring. Thus 25601 is the uppermost current meter on mooring 256 (I5) and 25604 would be the deepest on that mooring.

The current meter data.

The Aanderaa recording current meters used in this experiment recorded data internally on magnetic tape at 10 minute intervals throughout the record. The sampling is controlled by an internal crystal clock and timing errors were in all cases less than two minutes by the end of the experiment. Each instrument recorded current speed as an integrated value over the 10 minute sample period, current direction as a single value every 10 minutes of the orientation of the current meter value relative to magnetic north and water temperature from an externally mounted thermistor.

All the current meters had been individually calibrated prior to the experiment and it can be expected that the 10 minute current values should be accurate to within $\pm$ 1 cm/sec for speed and $\pm$ 1° in direction (50 cm/sec is approximately 1 kt).

At this stage no editing has been performed on the data series and as a consequence the plots show some "spikes" (bad data points), but the general interpretation of the data will not be affected. The data "spikes" have, of course, been ignored in determining the maximum current speeds.

Data Presentation.

Each current meter record is displayed as a time series of the 10 minute values of speed, east and north component and water temperature (figs. 3 to 21). Also plotted on the east and north components are time series of low-pass filtered data. (The filter cutoff is such that 24 hr period oscillations should be reduced to 3% of their original amplitude). These filtered values allow a better assessment of the relative contributions of high frequency (semidiurnal tidal) and low frequency (periods of several days) motions.

The plots of individual current components do not allow the direction of current flow to be easily recognised and so a series of "stick plots" (one for each mooring) are shown if figs. 22 - 26. These are shown as a series of vectors drawn at 12 hr intervals each representing the speed and direction of the low frequency current at that time. The combination of all the records from a mooring on one page allows a rough estimate of the vertical coherence to be made together with the amplitude and direction of the low frequency oscillations and of the mean flow.

All the time series plots are drawn on a common time axis from day 190 (July 9th) to day 255 (September 12th). August 1st is day 213 and September 1st day 244.

Description of the data.

All of the current records (figs. 3 - 21) show tidal oscillations which are present in both velocity components and in the current speed and whose amplitude varies throughout the record. The variations are not regular (i.e. they differ from current records on the continental shelf in which a regular springs/neaps variation in tidal amplitude can be detected). In motions and of their vertical coherence. Moorings I3 and I5 (255 and 256) show predominantly northward flow throughout the experiment. "Events" in the record seem to occur simultaneously throughout the water column and are in the same sense. e.g. around day 228 on mooring 256 the northward flow is stopped and turned towards the west at all depths. The periodicity of the low frequency fluctuations in these as in all the other records is close to 10 days. Mooring I4 (253) also shows coherent fluctuations but the northward mean flow is less well defined.

The influence of local bottom topography is seen in the deepest record on mooring 250 (I1). The strong oscillations are aligned parallel to the local depth contours and are rather dissimilar to the records at the two upper layers.

The lower part of mooring I2 (248) is influenced by the overflow from the Norwegian Sea and thus the 1000m record is strongly to the south compared to the records above it which are for the most part towards the east. The most striking feature of the three records on this mooring are the vertically coherent events near day 202 and 232 when the deep overflow is reversed. At all levels the change in current is of the order of 30 cm/sec. These two times approximately coincide with the only two periods during the JASIN experiment in which strong winds associated with the passage of depressions were experienced in the N. Rockall Trough. The later event is also seen in the records of mooring 256 (I5). In such short records it is possible that the coincidence of the meteorological and oceanographic events is fortuitous but if the summertime atmospheric disturbances can perturb the currents throughout the water column by as much as 30 cm/sec the typical winter storms in the area may in fact produce much larger features.

table 3 an attempt has been made to characterise each record by giving the typical and maximum observed values of tidal current amplitude.

The largest tidal signals are seen at the 1000m level on moorings 256 and 248. Both of these moorings are on the eastern side of the trough and the high tidal energy may be a result of their proximity to the Hebrides Shelf and the Wyville-Thomson ridge. The mechanism of the transfer of this tidal energy from the shelf to the deeper levels of the trough is not clear. The maximum tidal signals seen are of the order of $\pm$ 40 cm/sec (almost 1 kt). The values on other moorings are in the range $\pm$ 8 to $\pm$ 27 cm/sec. There is some evidence that the deepest records, from the 1000 and 1500m levels contain energy in the internal wave band - periods between 30 mins and 10 hrs - this shows as "noise" on the records and may not always be adequately resolved by the 10 minute sample period.

The highest 10 minute values are again on moorings 248 and 256 at the 1000m level, 68 and 55 cm/sec respectively. Mooring 248 is influenced by the overflow of water from the Norwegian Sea as it spills over the Wyville-Thomson Ridge. This accounts for the correlation of high currents with low temperatures on record 24803. The deepest current meter had a damaged rotor (perhaps by the high currents). This will have reduced its sensitivity but the speed channel shows that the currents were strong enough during overflow events (marked by low temperatures) to register values of up to 1 knot. It is reasonable to suppose that the true values greatly exceeded this.

Figs. 22 - 26 draw attention to the low frequency currents which remain after the tides and higher frequency motions have been filtered out and discarded. The plots give a good impression of the direction, amplitude and time scales of the low frequency

Engineering significance of preliminary results.

It is possible to see in the records described here several of the factors known to influence the currents in areas of the deep ocean adjacent to large topographic features. The dominant effects in these records are due to tides and to meteorological disturbances and in this particular area the energetic overflows of dense, cold water from the Norwegian Sea are an obvious feature of some of the deep records.

The relative importance of inertial oscillations, internal waves and mesoscale eddies will not become clear until more detailed analysis of the records has been performed. The full effects of the overflows from the Norwegian Sea have not been monitored due to damage to the current meter (perhaps caused by the high currents).

The importance of episodes of extreme current, which will be of interest in the design of engineering structures, is difficult to assess from such short records from the summer season. One crude estimate of possible maxima is made by combining the maximum tidal amplitude observed with the maximum low frequency signal and assuming that the two are coincident. This operation results in extremes of 77 and 59 cm/sec on moorings 248 and 256 respectively, of the order of 40 cm/sec on moorings 250 and 255 and 29 cm/sec on 253. These results show clearly that the strongest currents may be encountered close to topography and on the eastern side of the basin. Longer observations can only serve to increase these extreme values.

The magnitude of vertical shear both at tidal and lower frequencies cannot yet be assessed from the preliminary analysis but is certain to be of importance in the design of structures. The measurements made in this experiment do not consider the upper 200m of the water column where both shear and extreme values of current may be expected to be large.

Appendix.

Scientific development of the experiment

The measurements reported here were designed to study the circulation of the Northern Rockall Trough and to learn something of the physical processes responsible. Previous current measurements in the area had shown oscillations with periods of 5 to 10 days and it was thought that they might be driven by atmospheric pressure and surface winds acting on the ocean. Because of the meteorological measurements being made, the JASIN experiment presented a good opportunity to study this connection.

Most of what is known of the long term water flow through the region has been inferred from studies of the different types of water, within and around the Rockall Trough. This suggested that at the surface there is a northward flow along the eastern side of the Trough. Near the bottom the cold water which spills over the Wyville-Thomson ridge is thought to run as a current along the northern and western sides of the Trough.

The Trough is large enough to contain mesoscale eddies which are a feature of other parts of the N. Atlantic. These are circulation features equivalent to the cyclones and anticyclones of the atmosphere, but with diameters of only 100km or so. They take 100 days or more to pass a point.

Some previous current measurements made in the Trough showed current oscillations with periods of 5 to 10 days. Such oscillations are not normally very noticeable in current records from the deep ocean despite the fact that this is the frequency range in which one would expect atmospheric forcing to be greatest. Five to ten days is the period of the main internal seiche of the Trough and the oscillations could therefore be the response of this seiche to atmospheric forcing. (An internal seiche is a standing internal wave in which the surface water level remains roughly constant but the internal density surfaces are displaced accompanied by current shear across the density surface).

Continental shelf waves with periods of a few days are waves which are trapped against the continental shelf by the Coriolis force. The associated currents are greatest on the shelf and at the shelf edge and decay as one moves into deeper water. Such continental shelf waves in the Rockall Trough would move anti-clockwise around the basin.

At periods of a day or less, there are a number of wave motions which occur in current measurements. Tidal currents are usually the most important in the eastern Atlantic. There are also inertial oscillations (natural horizontal oscillations of the ocean associated with the earth's rotation), and internal waves associated with oscillations of the density surfaces.

Selection of mooring positions.

The initial plan was to form, together with the SMBA moorings E3 and E4, a hexagonal array of moorings with one central mooring. This would give good geographical coverage of the northern Rockall Trough. During the planning of JASIN, I3 was moved away from the shelf so that density measurements could be made around it. Also we learned that the Marine Laboratory, Aberdeen of DAFS were planning to place a mooring (D2) near the original position of I5. The modified positions of I3 and I5 and the positions of the other deep current meter moorings are shown in fig. 1.

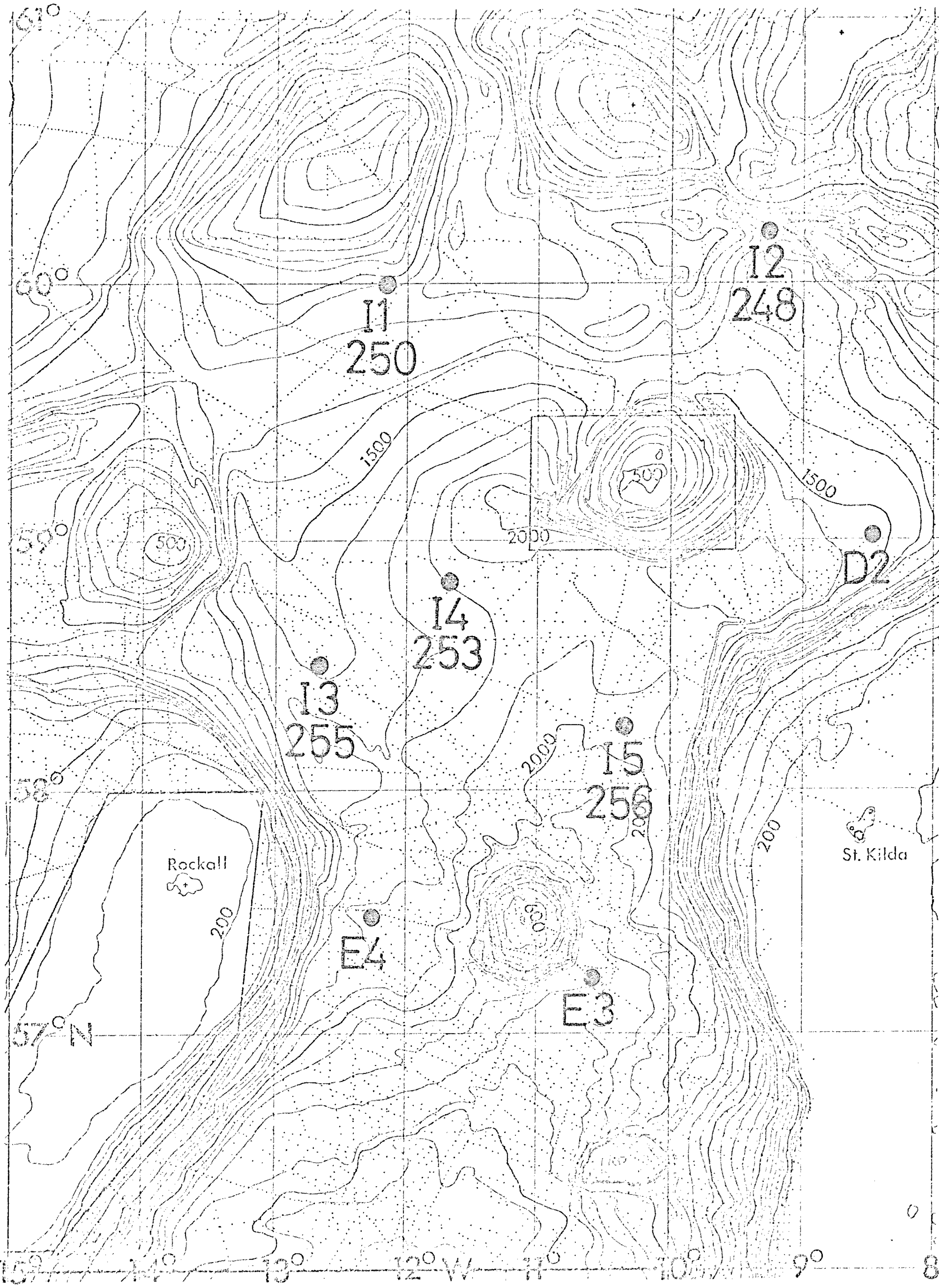
This array of widely spaced moorings should enable us to map the mean flow through the area. Mooring I2 was positioned to monitor any water flowing over the Wyville-Thomson ridge.

The moorings are too far apart to map the mesoscale eddies but these might be mapped from the combination of the current measurements with the density observations.

The array should be suited for studying oscillations with periods of 5 to 10 days because both the surface and internal waves of this period are expected to have wavelengths larger than the separation of the moorings. This is also true for the main surface tide. However, the other high frequency oscillations mentioned have much shorter wavelengths. For these oscillations the horizontal and vertical spacing of the current meters is too great to define their detailed structure and thus they will only be studied in a statistical sense.

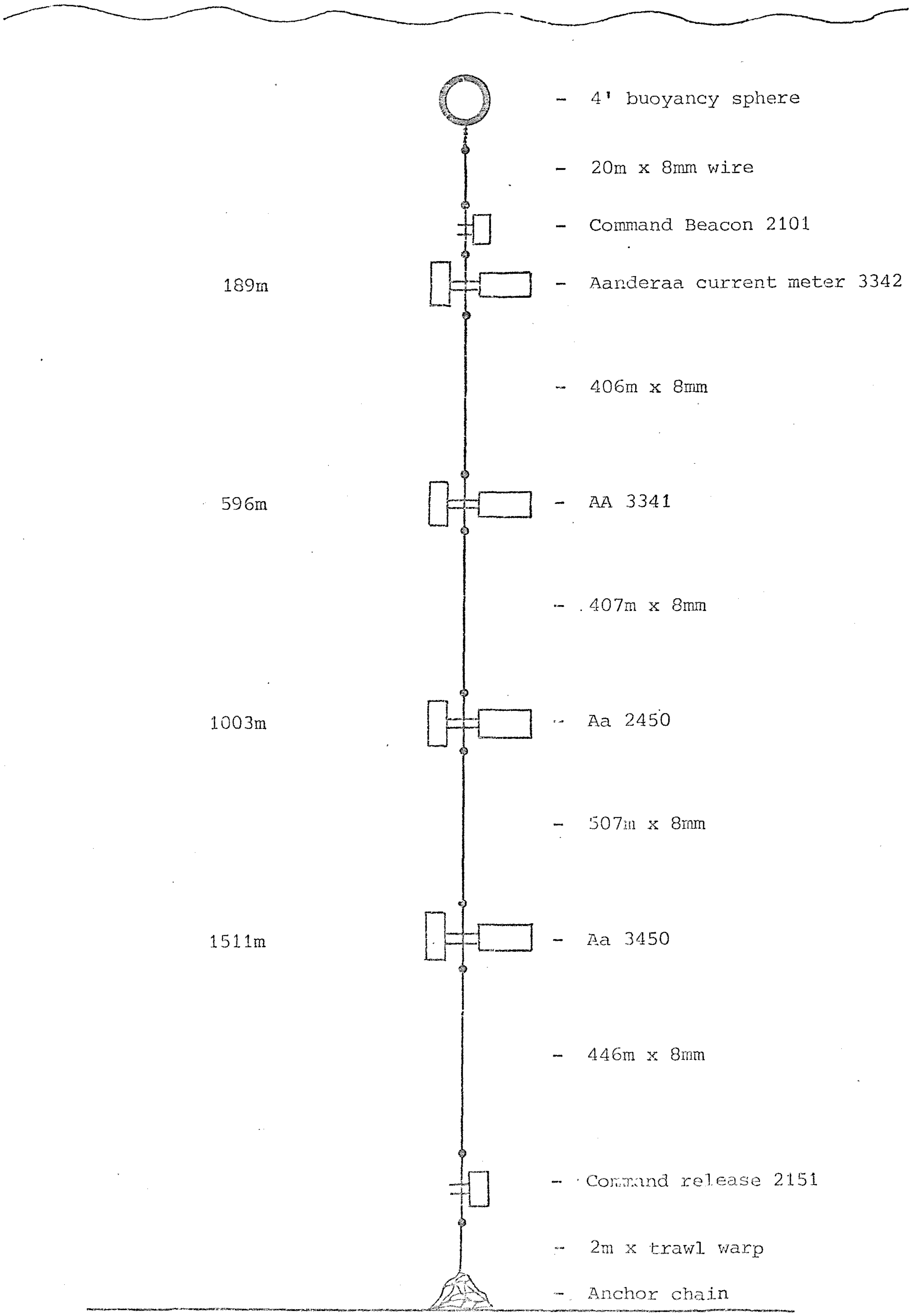
Finally in positioning the moorings the continental slopes were avoided, partly due to the difficulty of setting moorings on steep slopes but also so that these initial measurements are not too confused by the complexities of a full spectrum of shelf waves and locally generated internal waves.

Fig. 1.



61°
60°
59°
58°
57° N
15°
14°
13°
12° W
11°
10°
9°
8°
I1
250
I2
248
I3
255
I4
253
I5
256
D2
E3
E4
1500
1500
500
500
2000
2000
200
200
Rockall
St. Kilda

Fig. 2



4' buoyancy sphere
20m x 8mm wire
Command Beacon 2101
189m
Aanderaa current meter 3342
406m x 8mm
596m
AA 3341
407m x 8mm
1003m
Aa 2450
507m x 8mm
1511m
Aa 3450
446m x 8mm
Command release 2151
2m x trawl warp
Anchor chain

TABLE 1

Mooring number JASIN/IOS	Position		Water depth (M)	Date set	Recovered
I2/248	60°11'.7N	09°15'.4W	1444	14-VII	6-IX
I1/250	59°59'.2N	12°09'.1W	1117	15-VII	4-IX
I4/253	58°49'.8N	11°39'.8W	1821	17-VII	27-VIII
I3/255	58°30'.0N	12°40'.2W	1591	18-VII	1-IX
I5/256	58°15'.0N	10°20'.2W	1960	18-VII	25-VIII

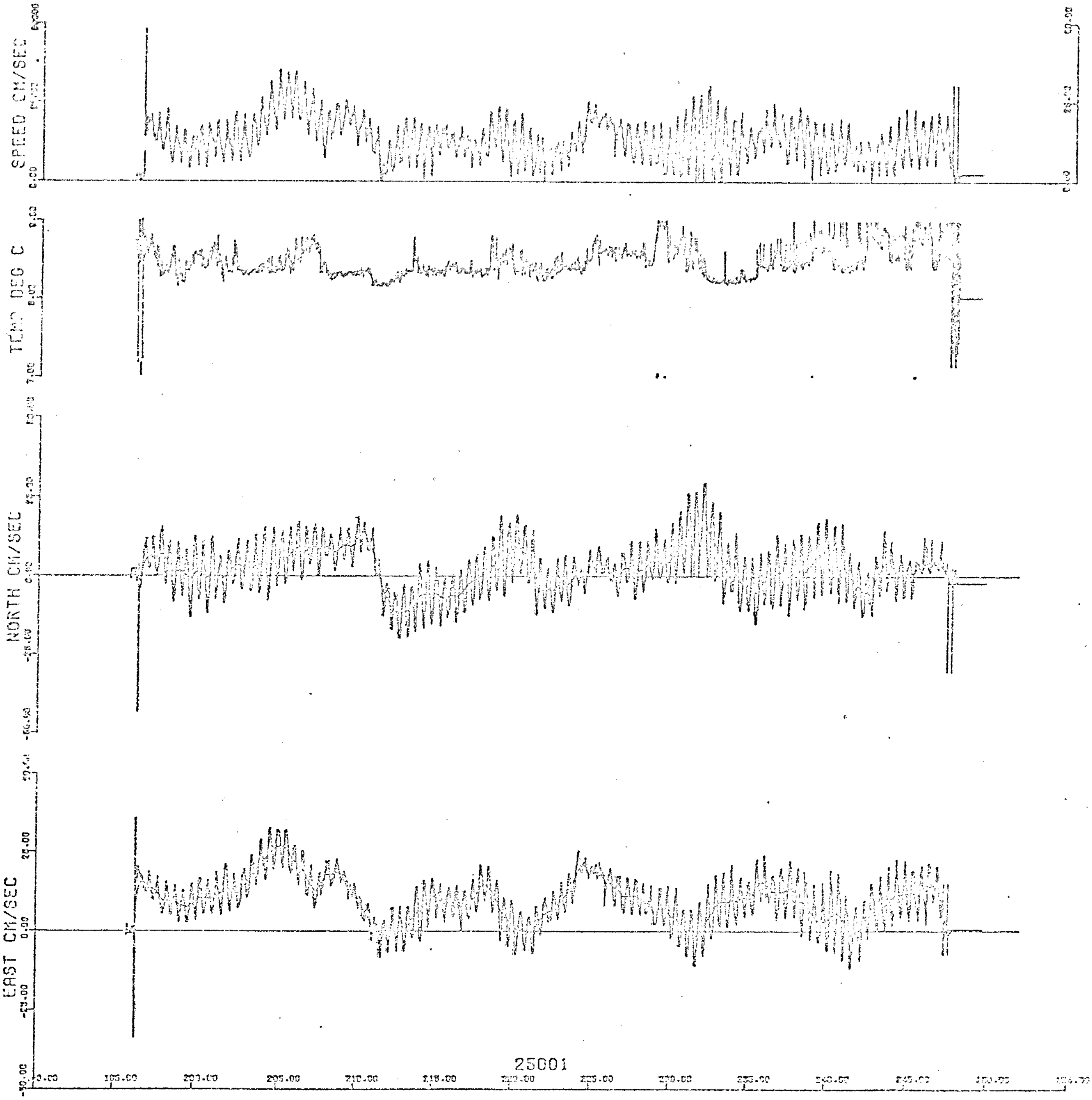
TABLE 2

I2 (248)	24801	211m	I3 (255)	25501	189m
	24802	615m		25502	595m
	24803	1032m		25503	999m
	24804	1396m		25504	1503m
I1 (250)	25001	254m	I5 (256)	25601	189m
	25002	660m		25602	596m
	25003	1066m		25603	1003m
				25604	1511m
I4 (253)	25301	198m			
	25302	607m			
	25303	1016m			
	25304	1522m			

TABLE 3

All speeds in cm/sec

Depth	Mooring	Tidal amplitude Typical	Tidal amplitude Max	Max 10 minute average speed	Max low freq. speed
	250	10	13	33	27
	248	20	25	46	37
200m	255	10	15	35	17
	253	6	8	25	16
	256	6	10	31	23
	250	10	13	30	22
	248	20	27	40	33
600m	255	12	15	30	21
	253	6	10	26	16
	256	7	15	35	26
	250	12	18	34	22
	248	25	40	68	37
1000m	255	15	22	28	17
	253	7	12	23	11
	256	15	40	55	19
	248	No Data		No Data	No Data
	255	6	10	25	15
1500m	253	10	15	23	14
	256	15	20	25	8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EAST CM/SEC
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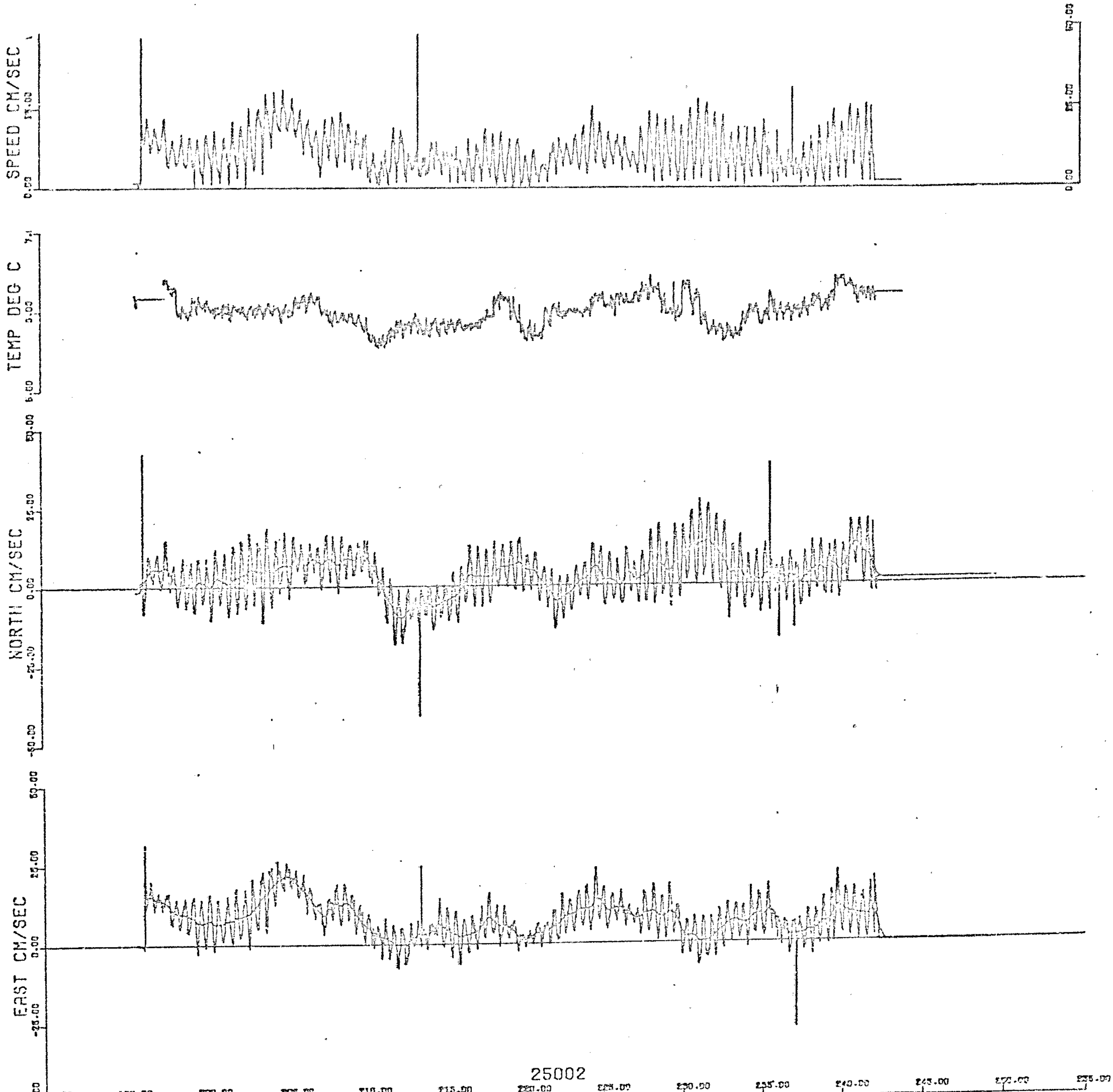
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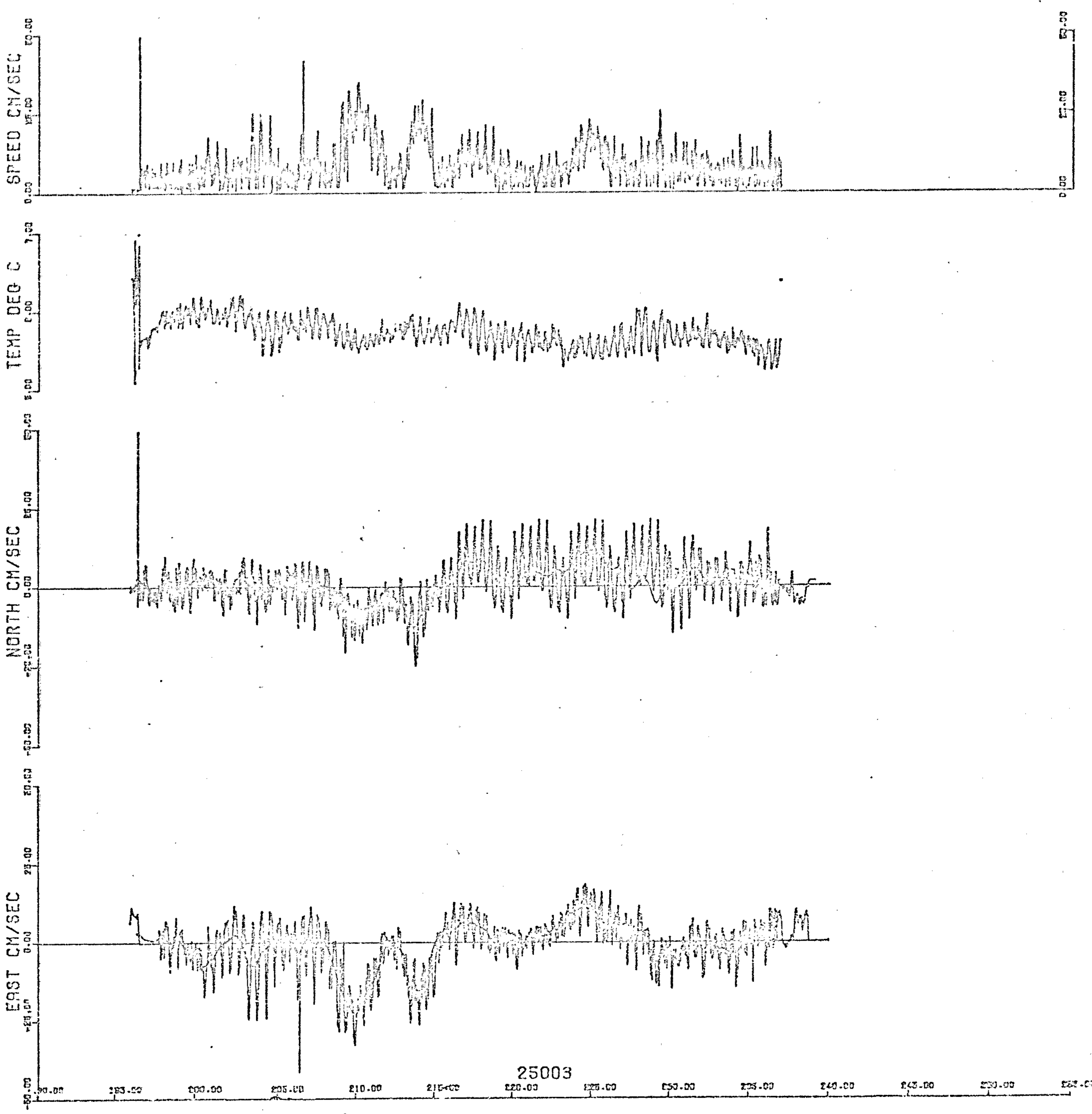

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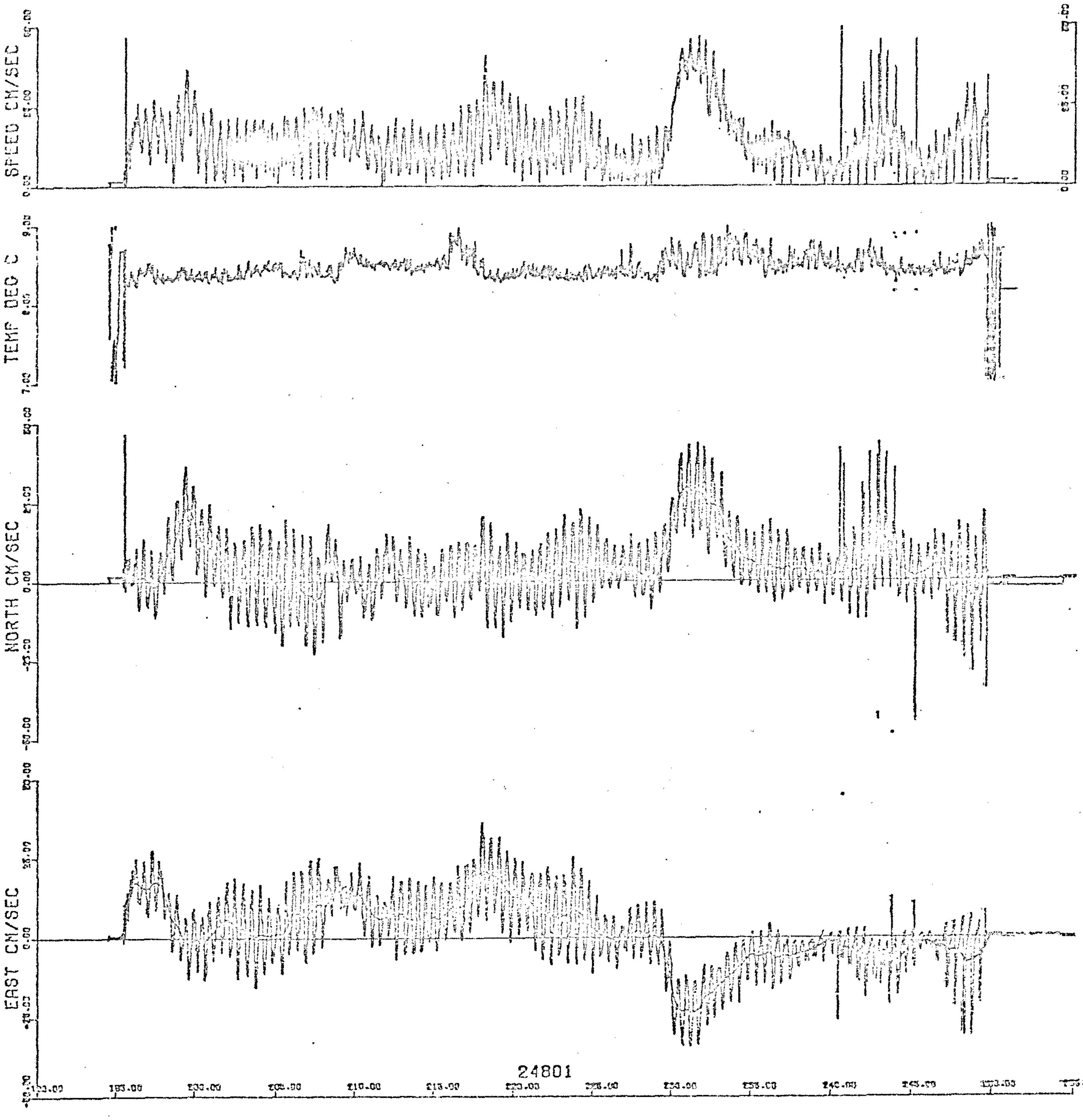
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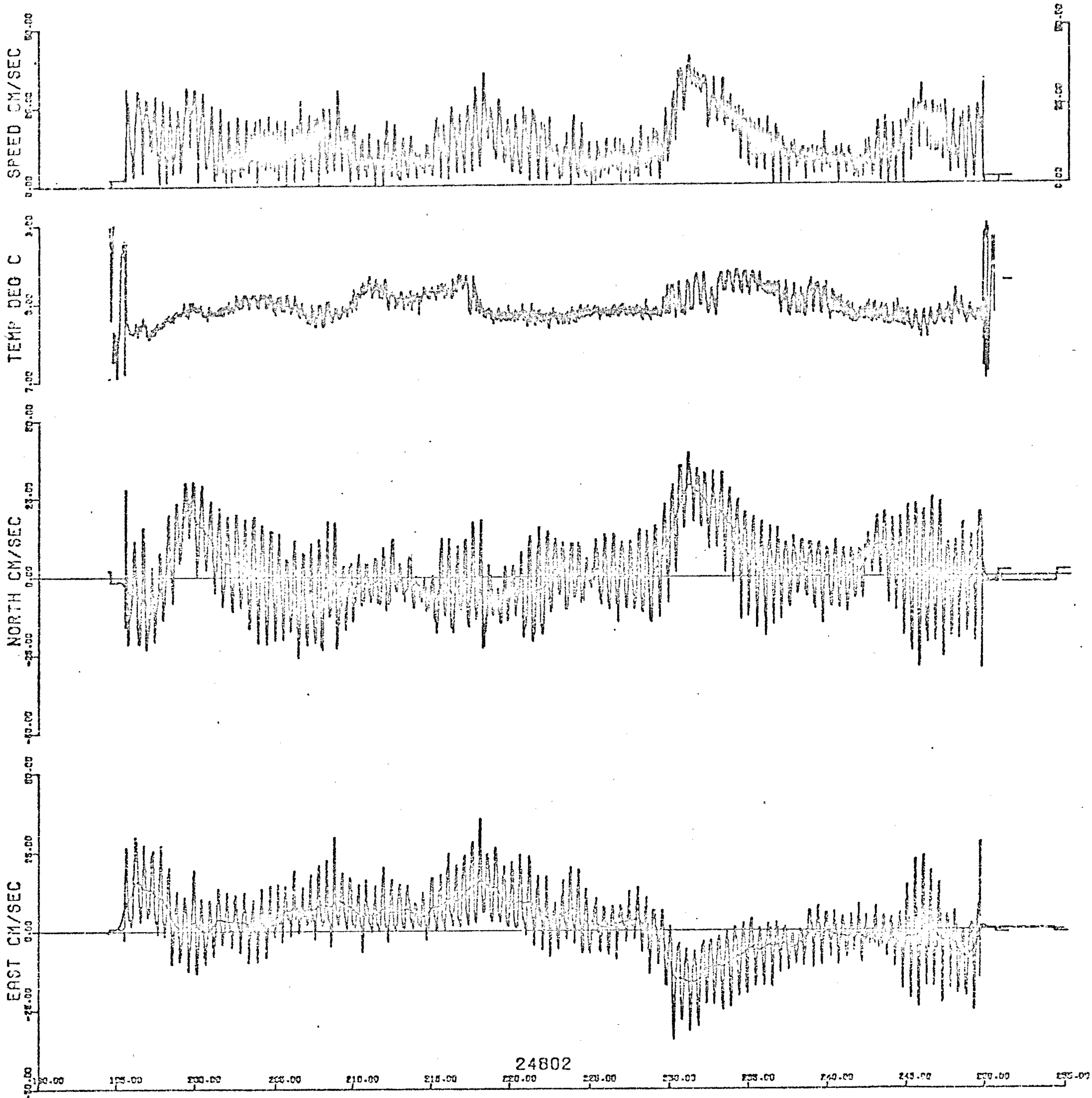
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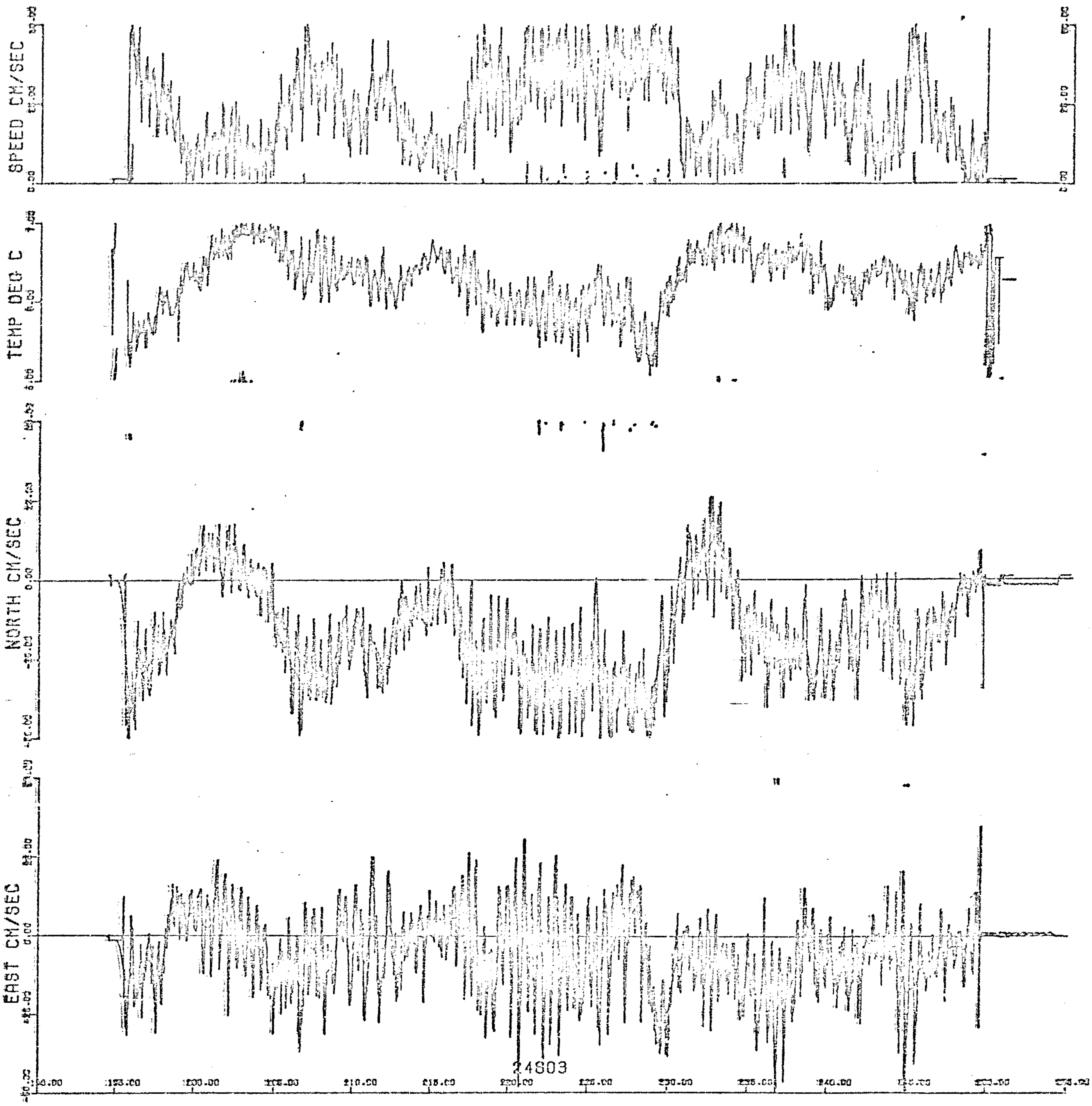
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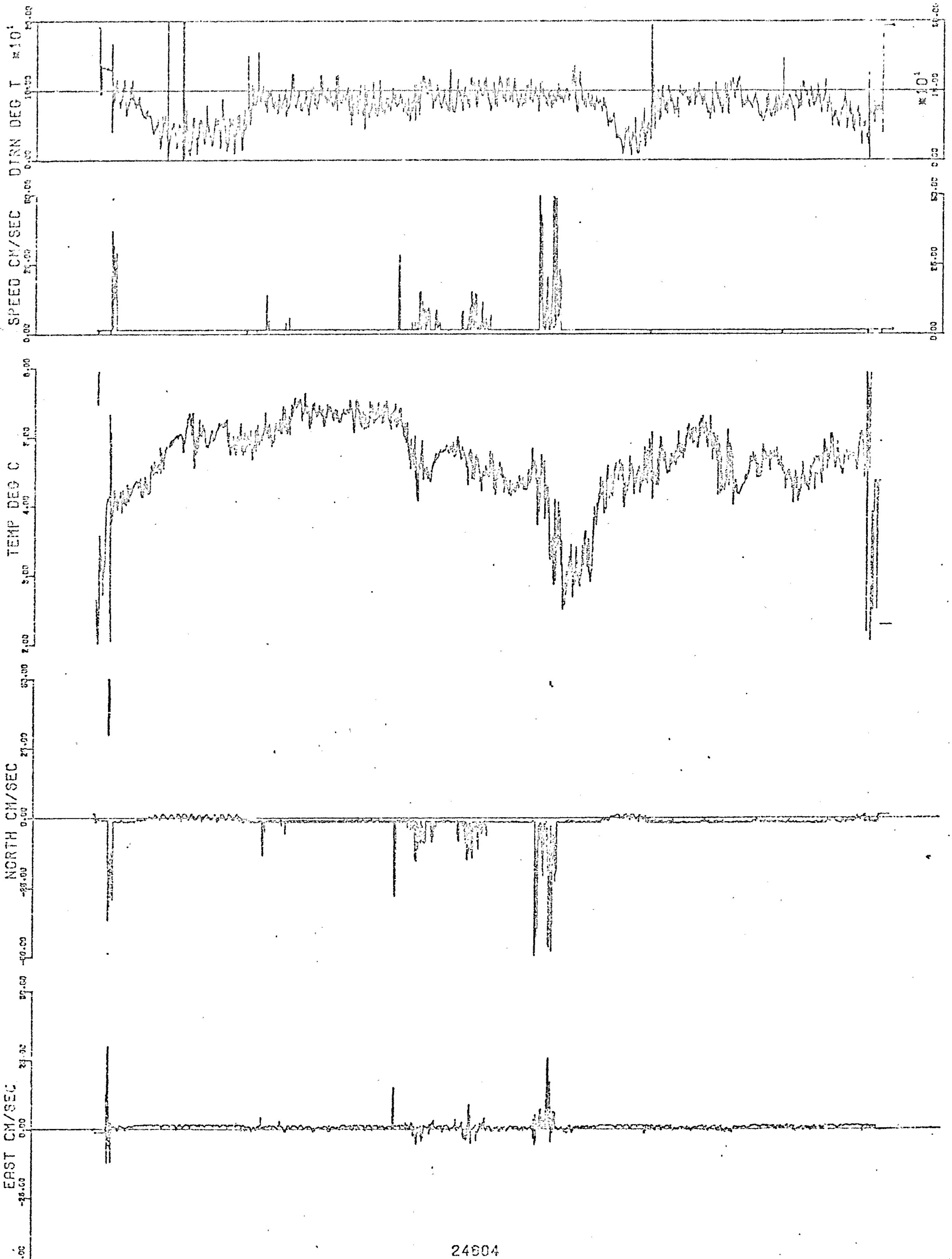

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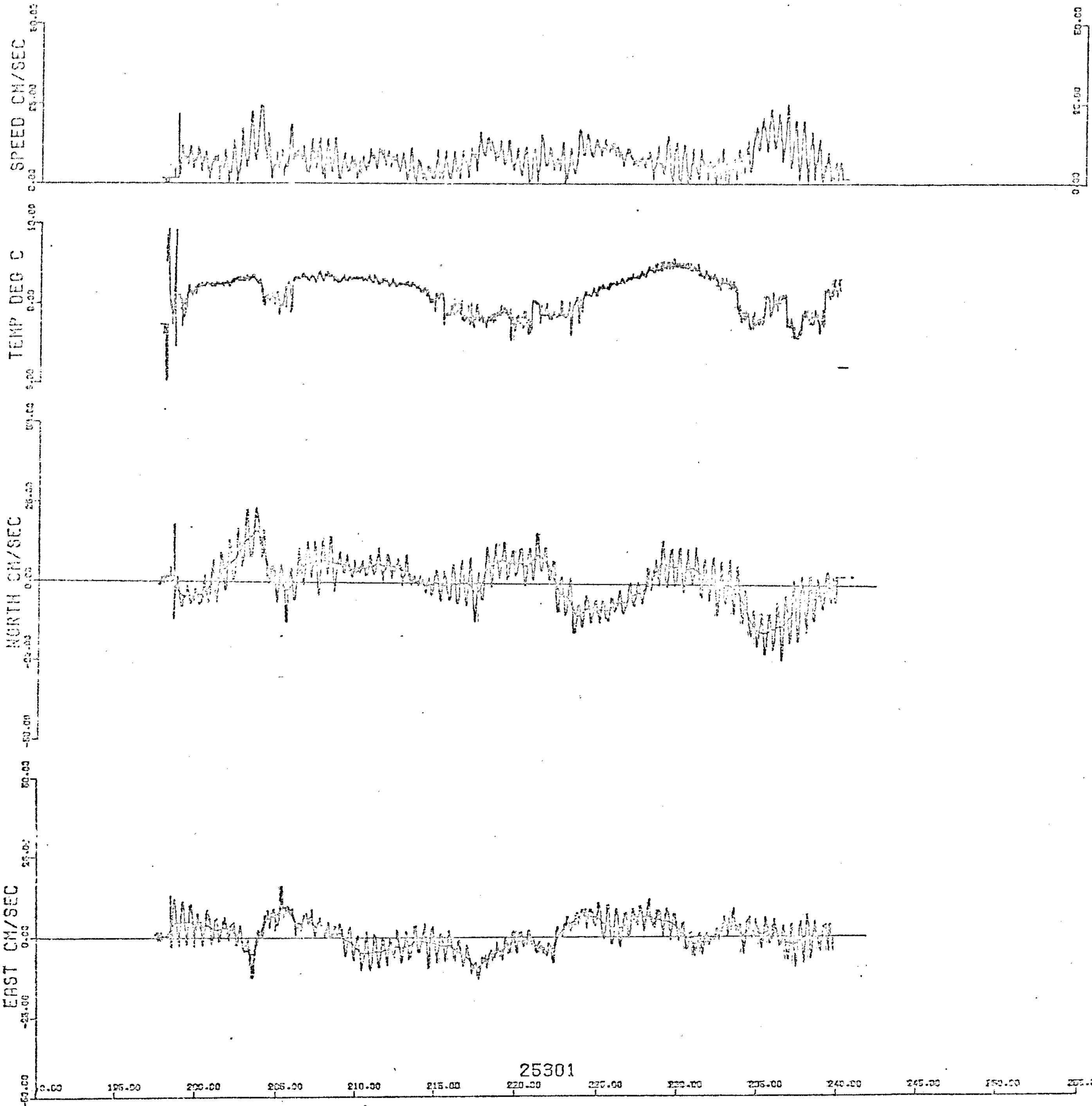
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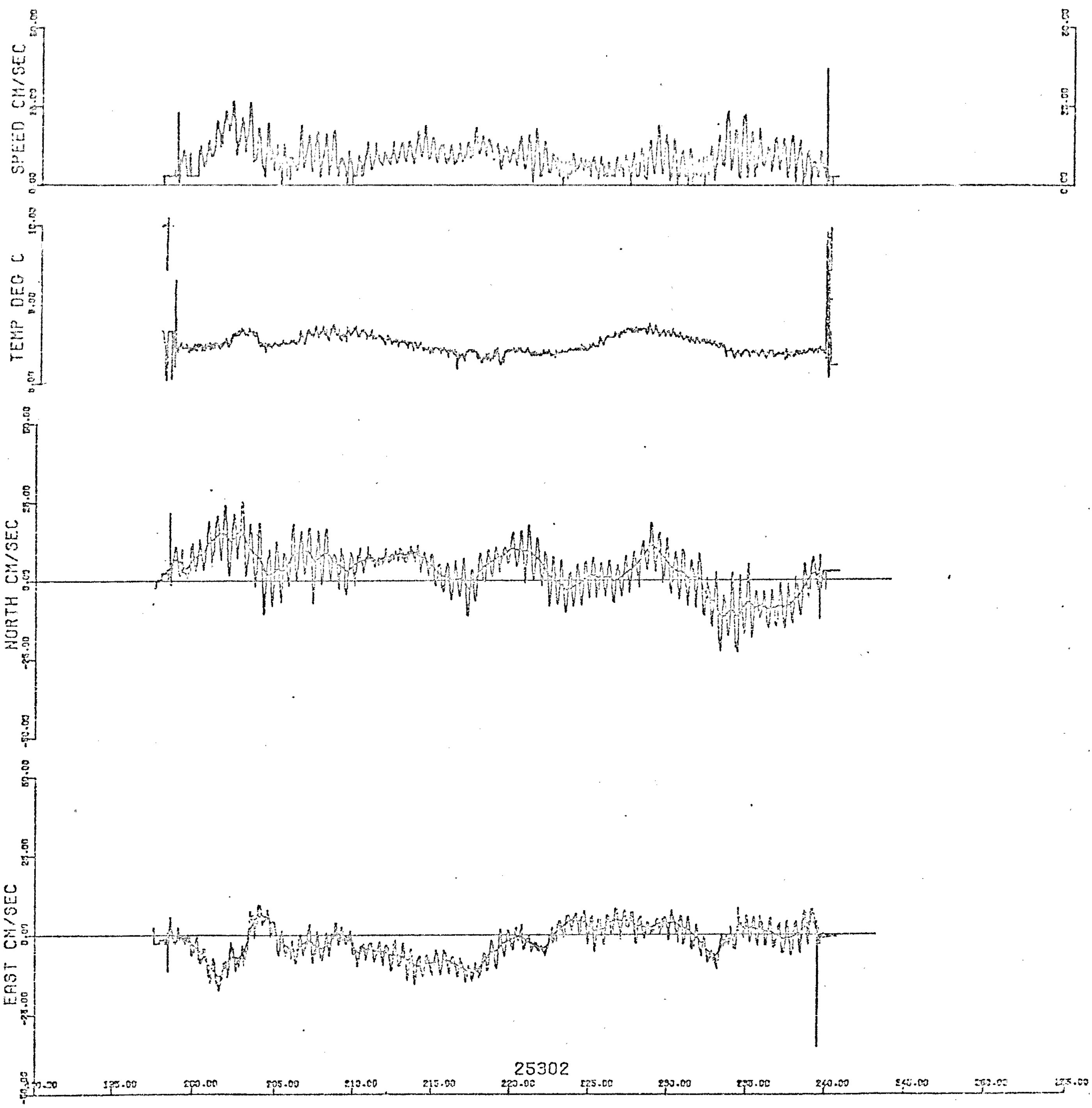
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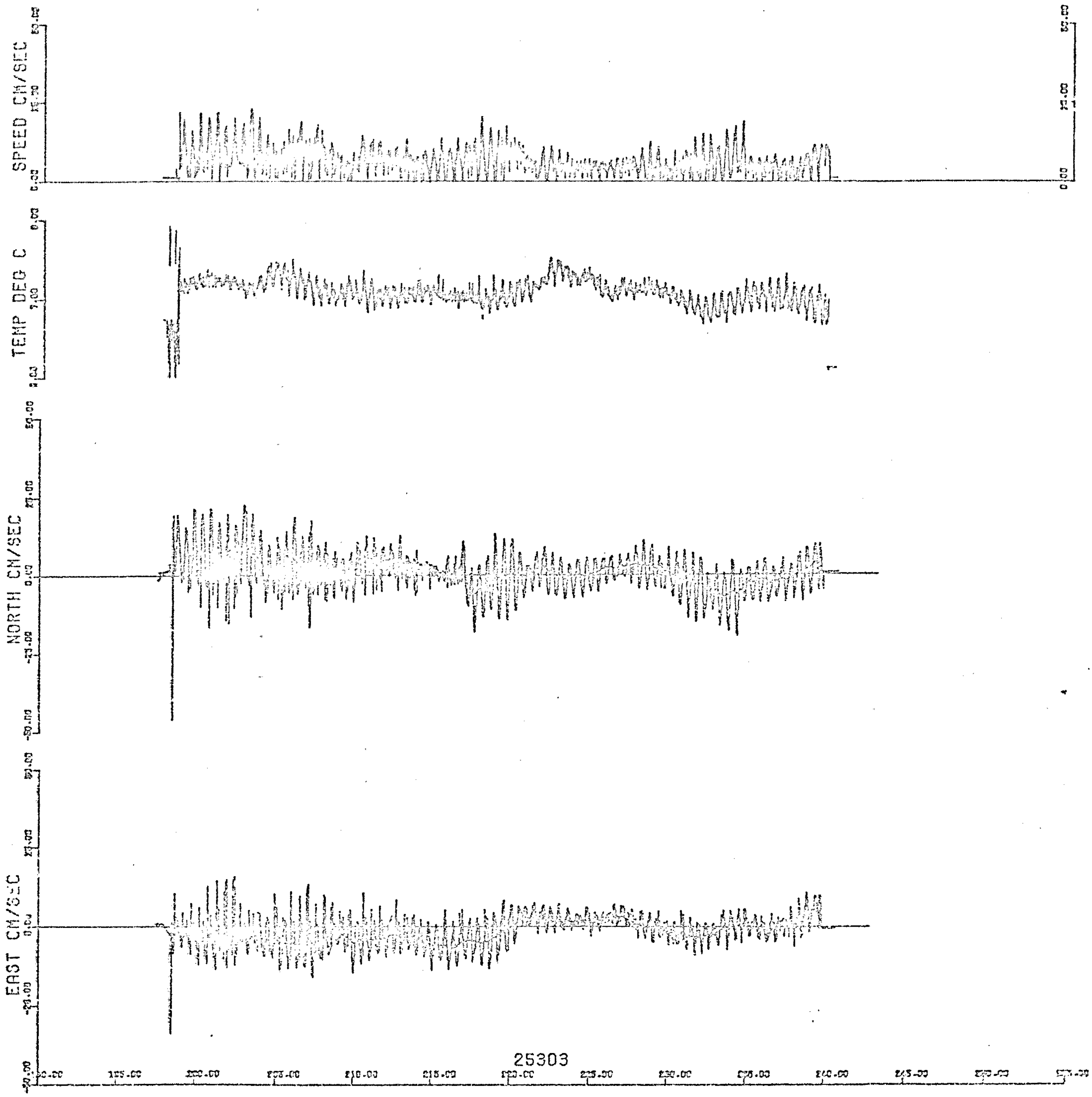
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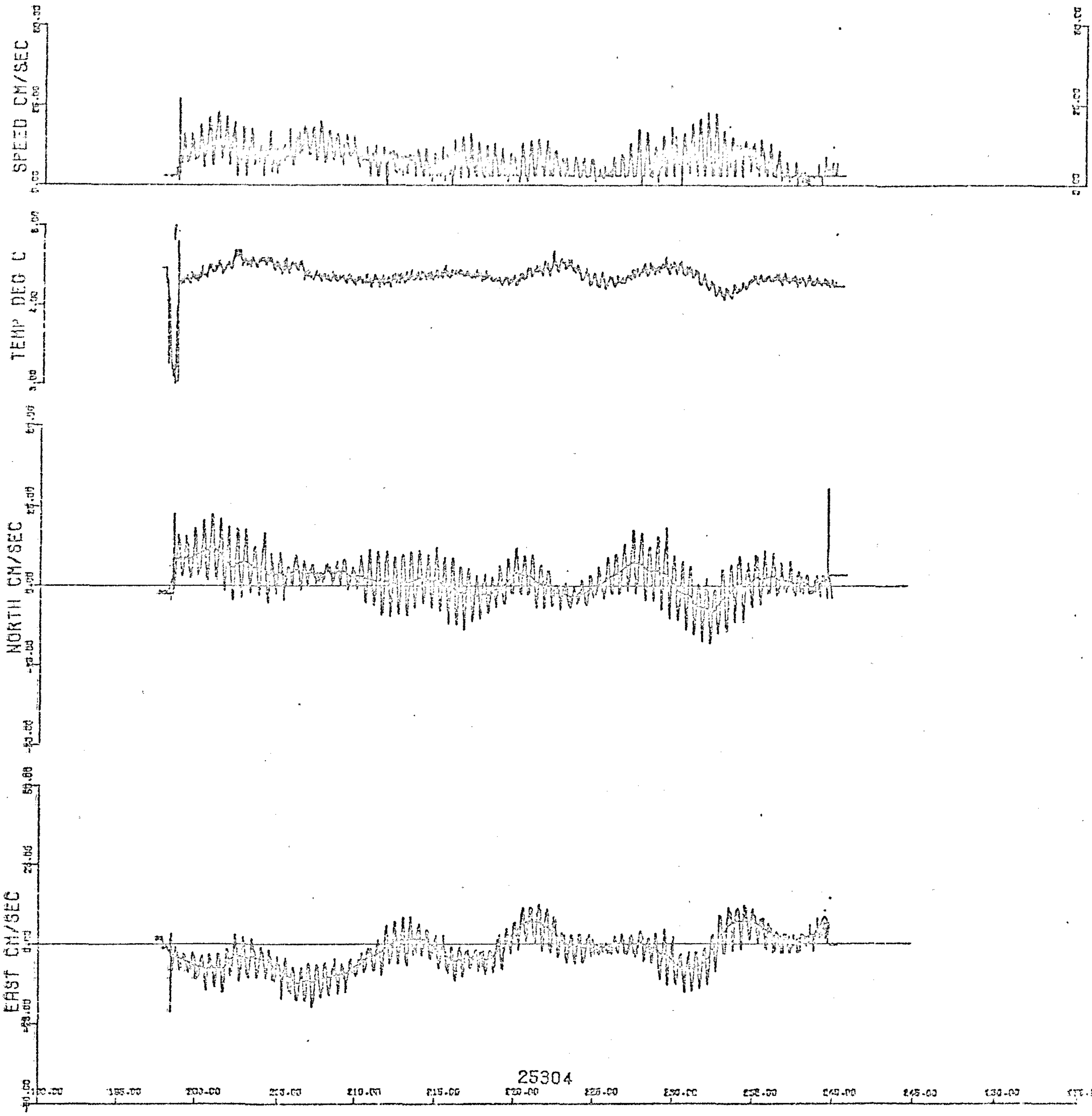
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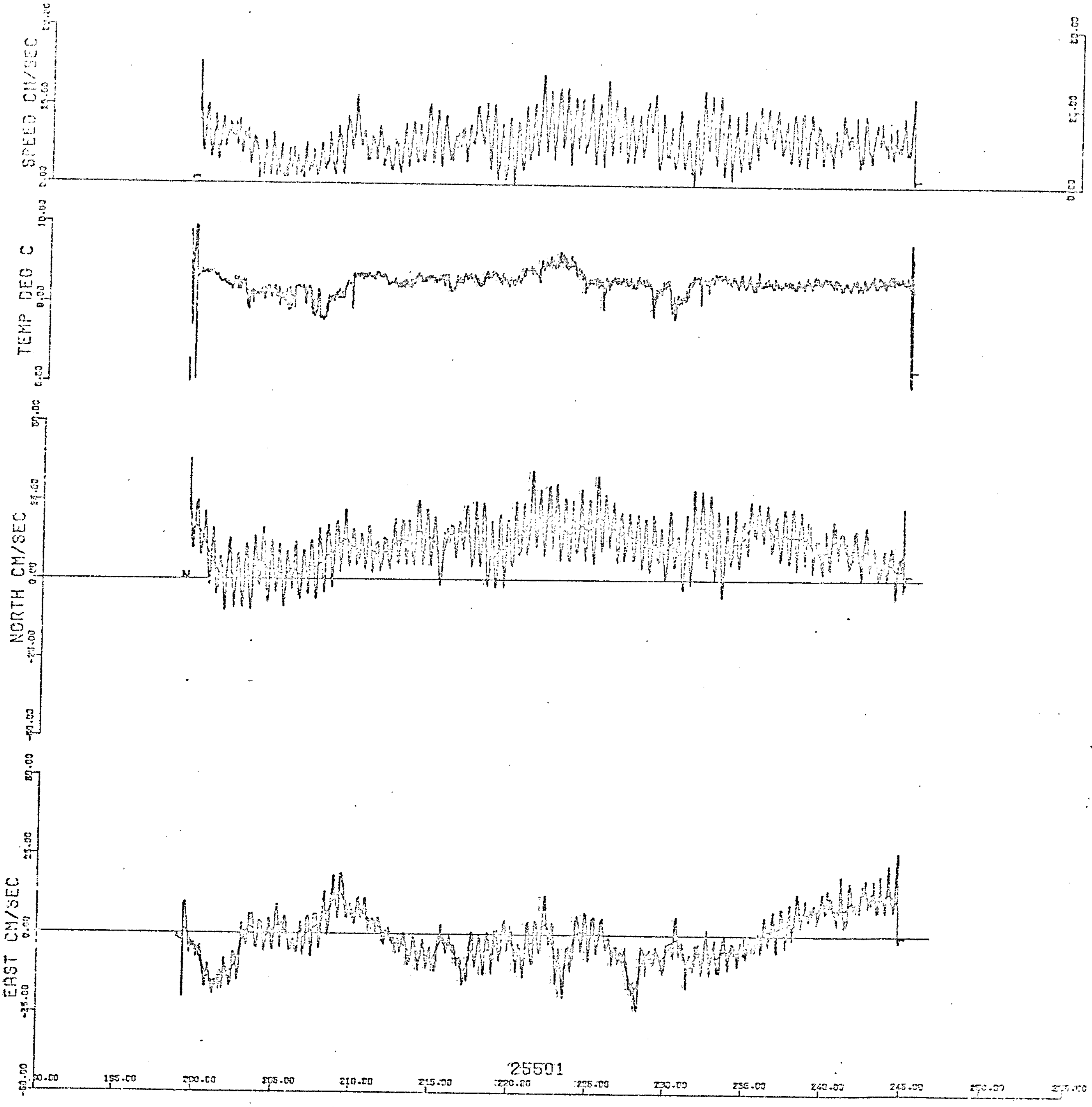

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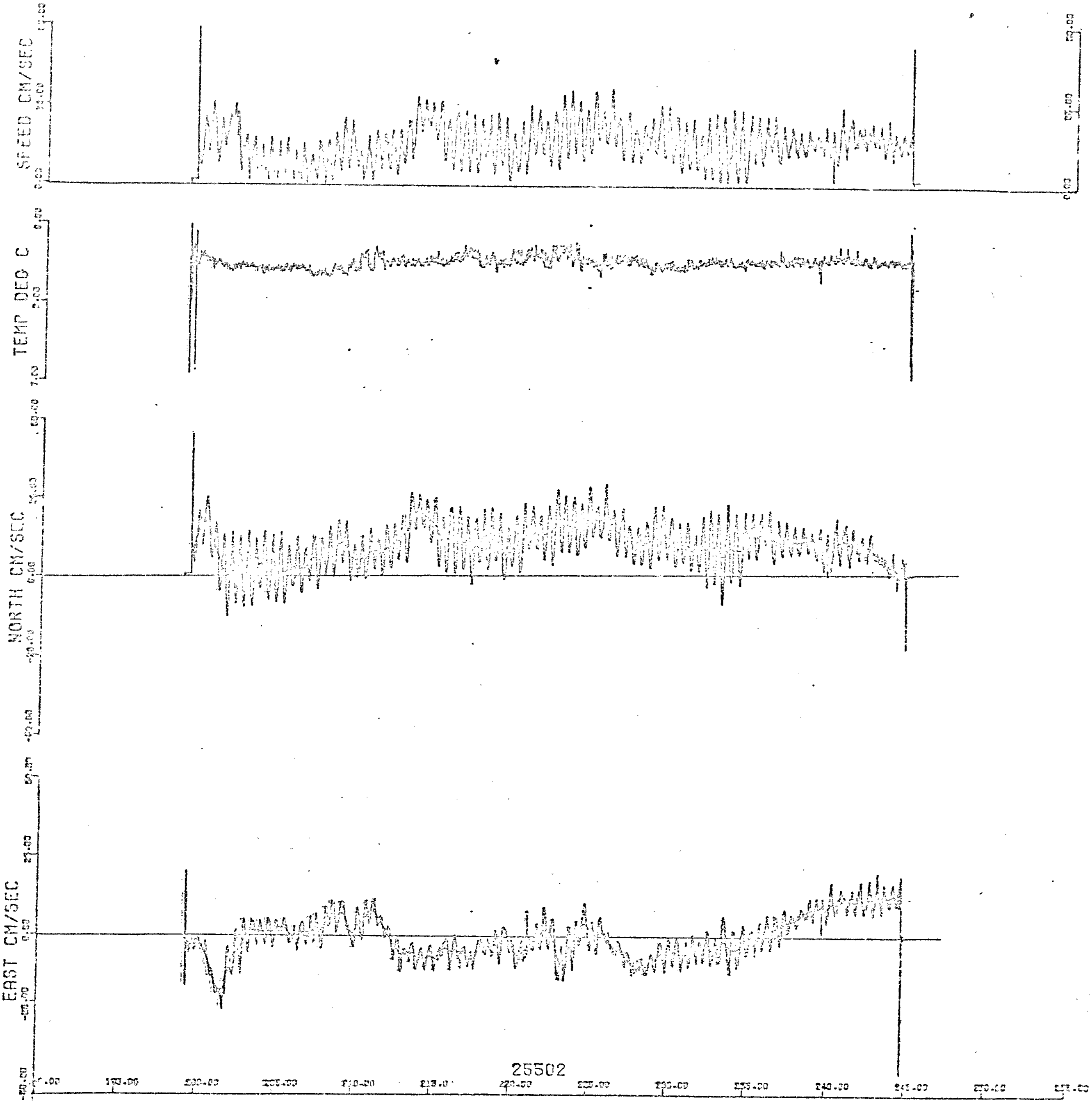
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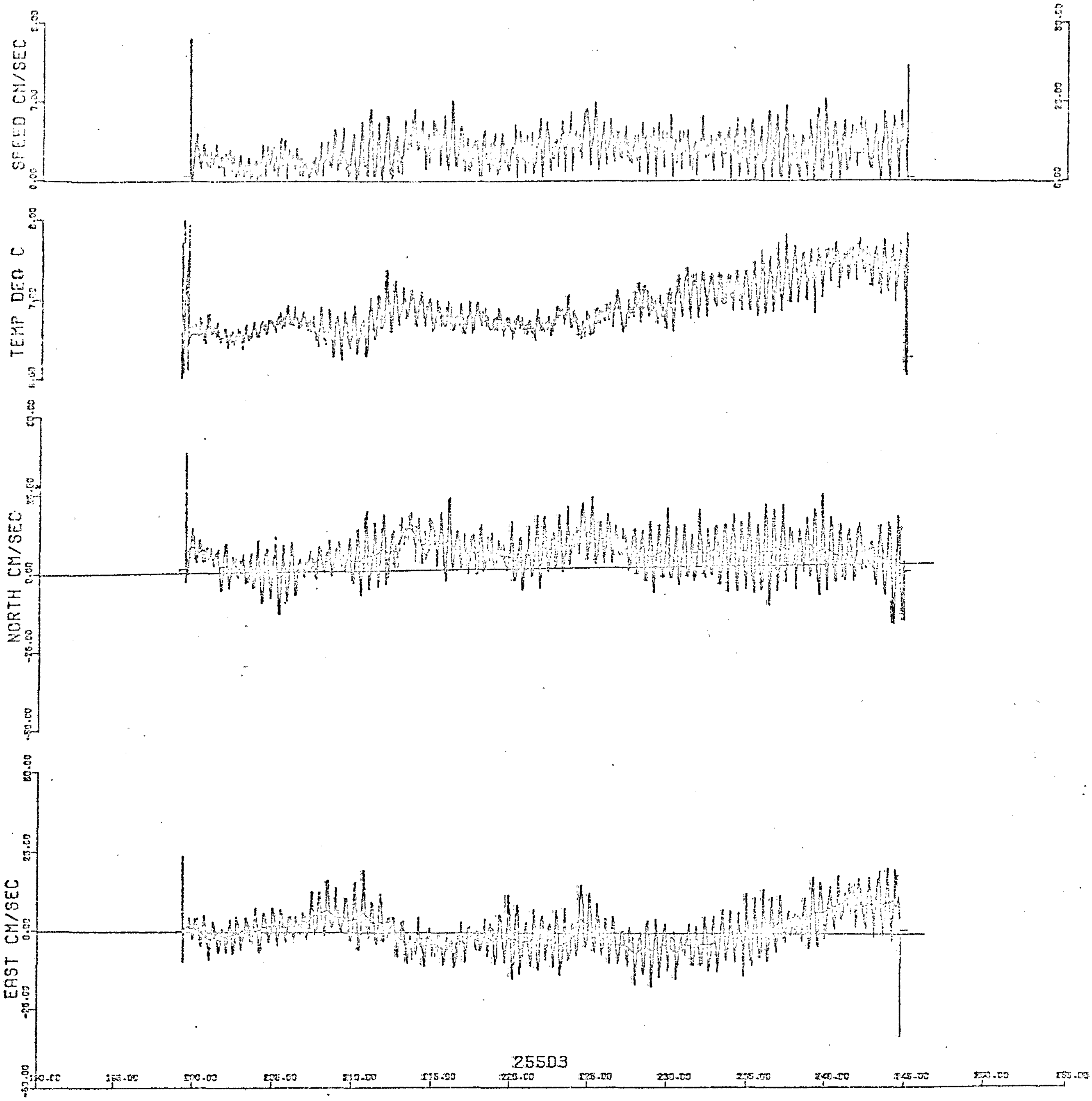
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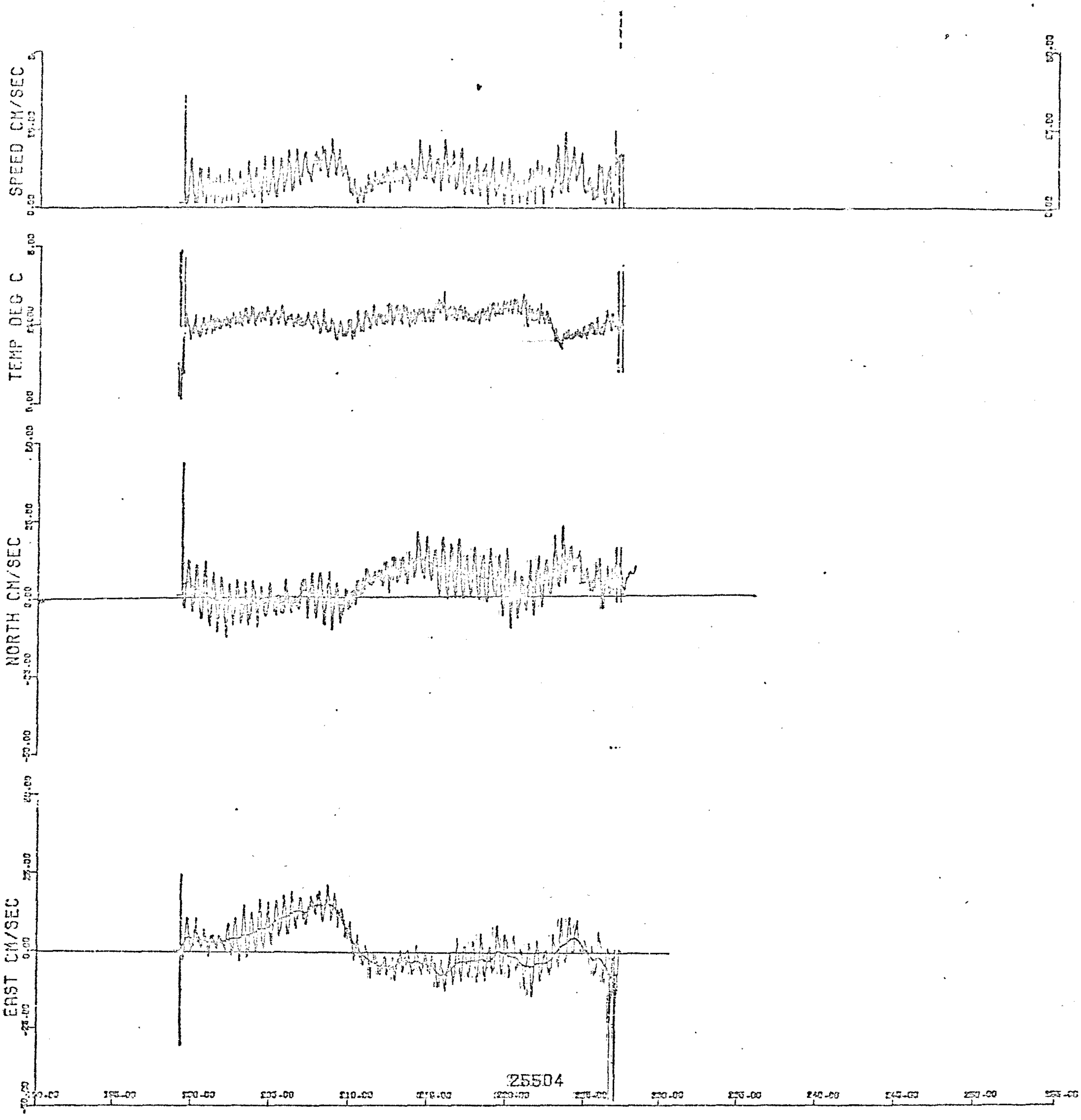
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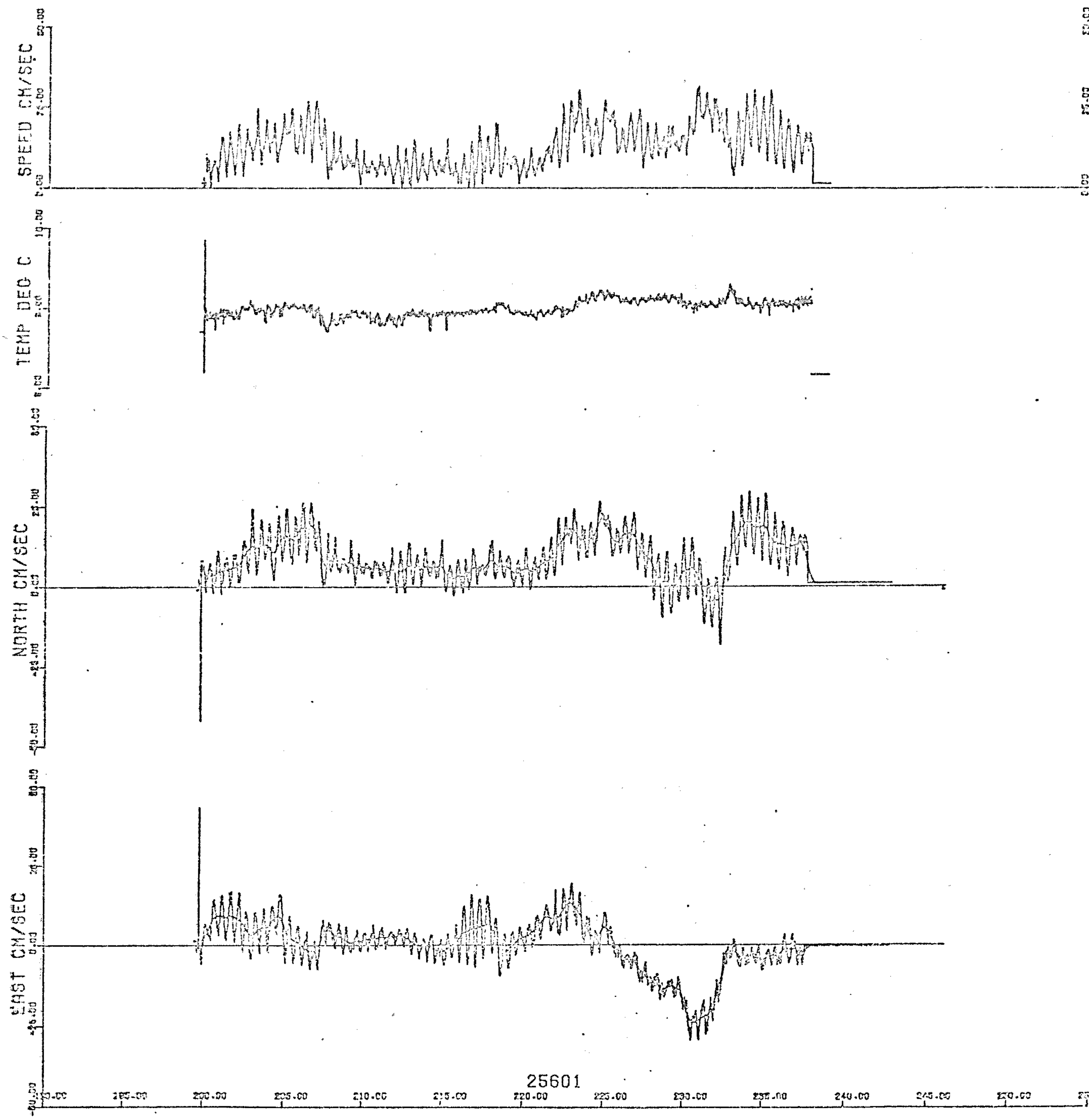

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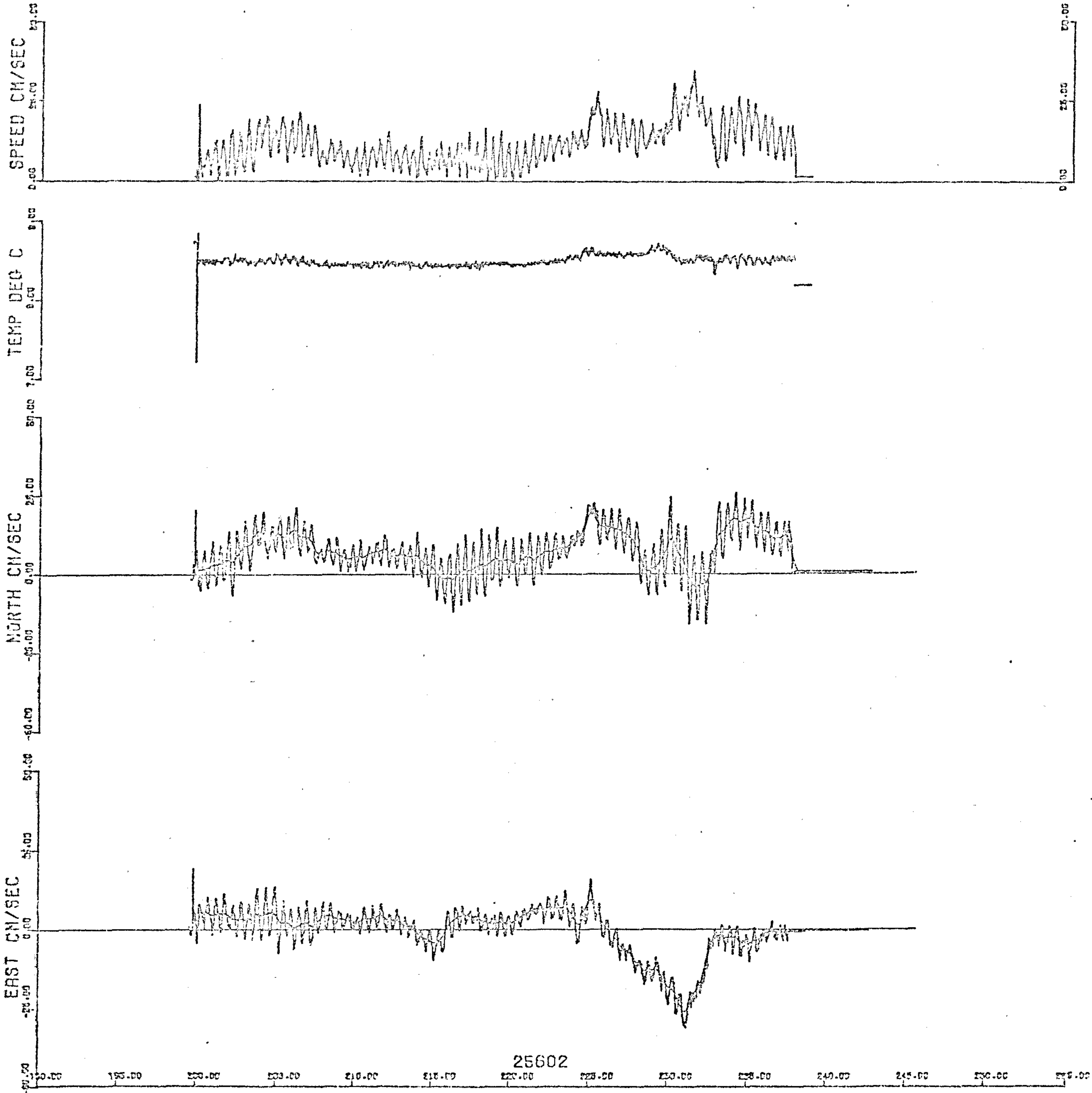
240.00
245.00
250.00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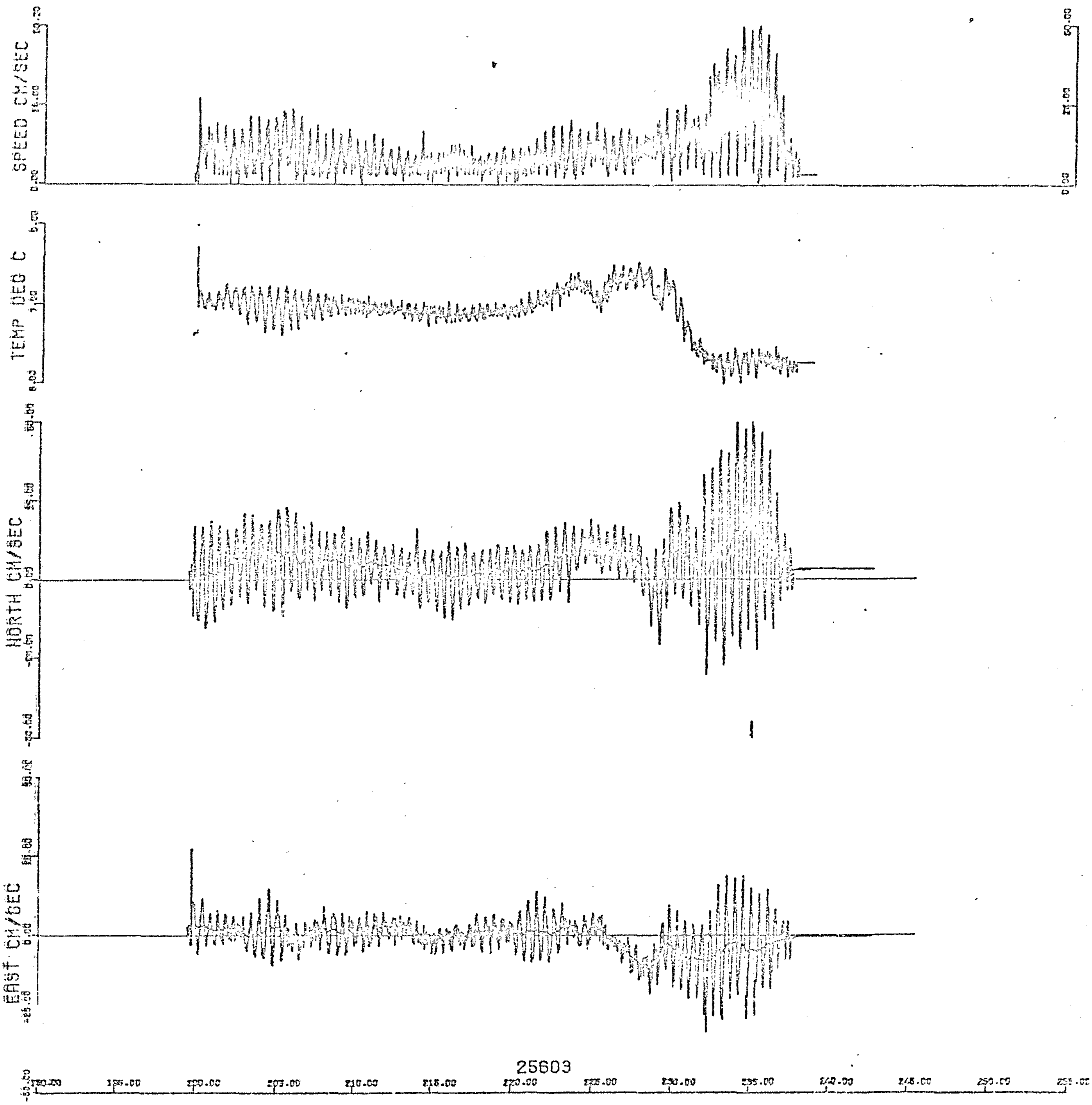
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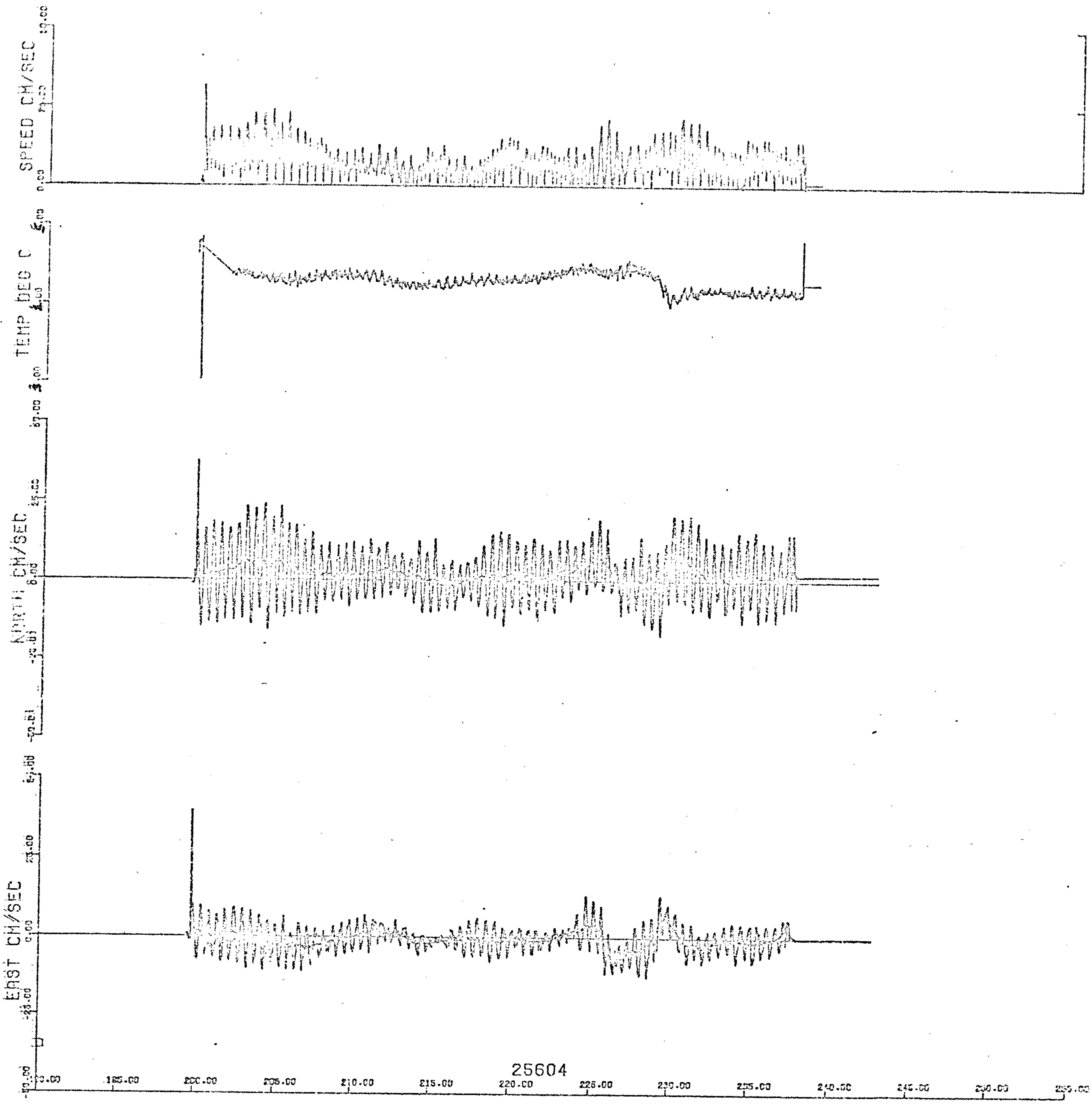

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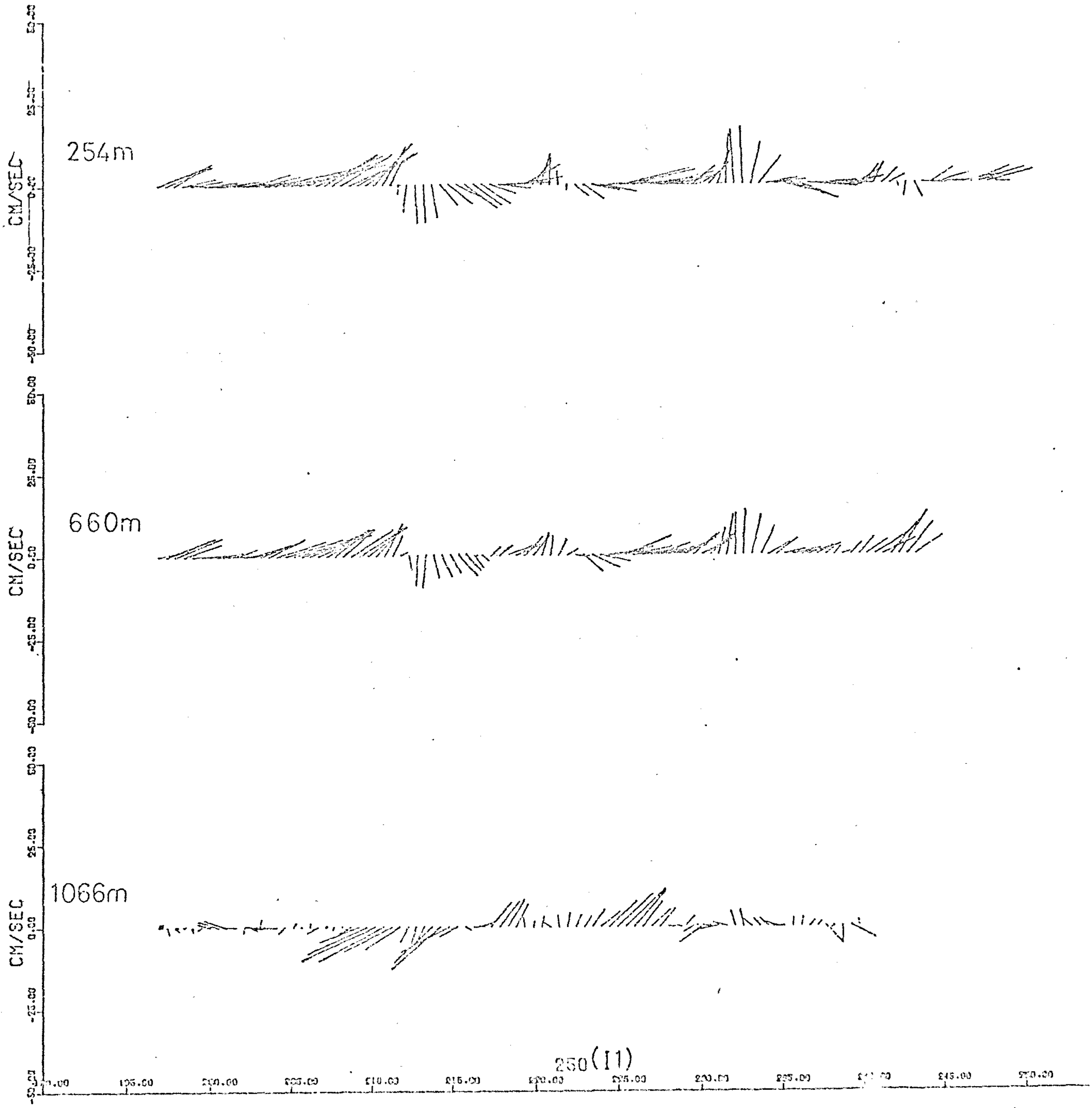
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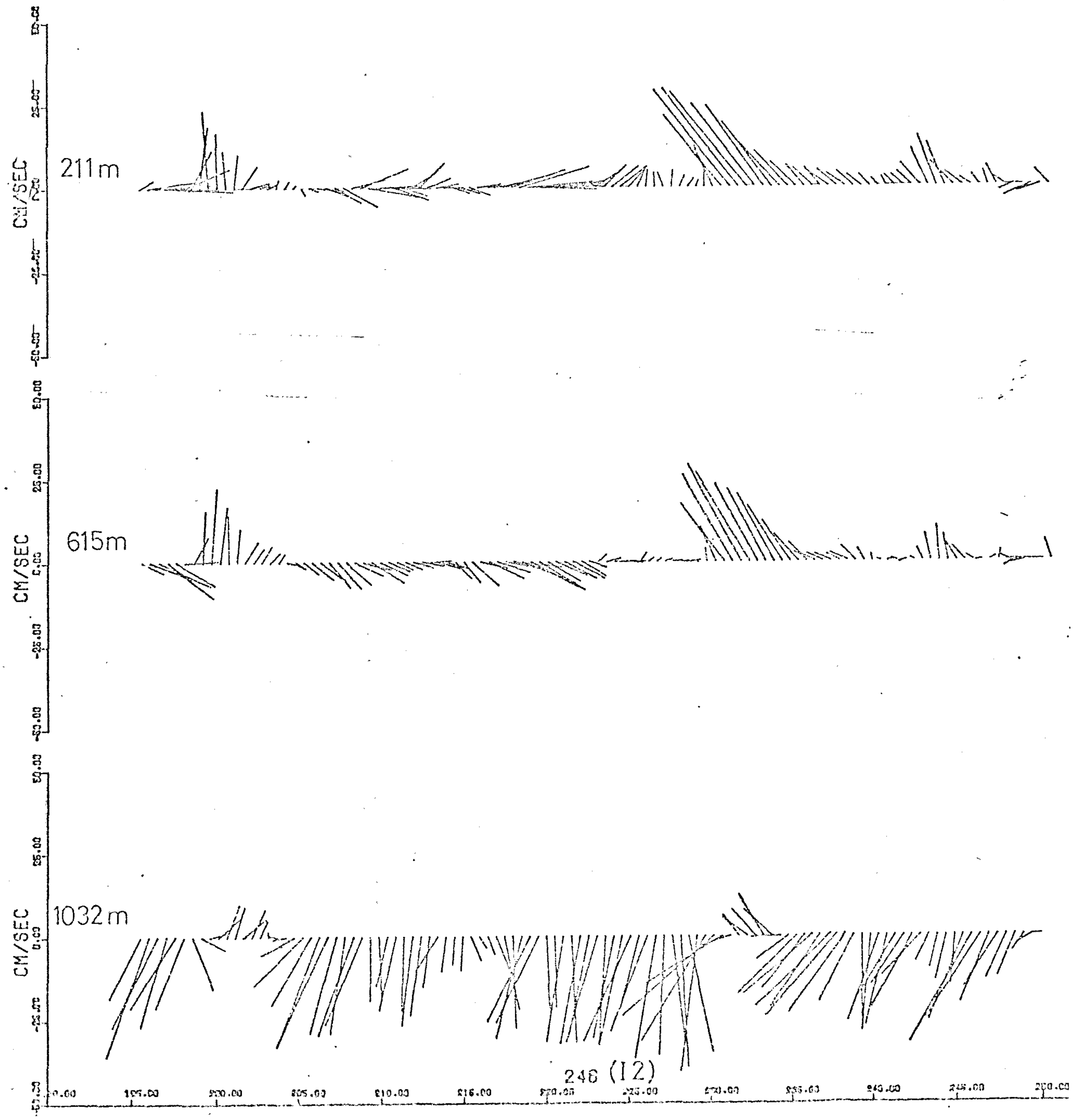
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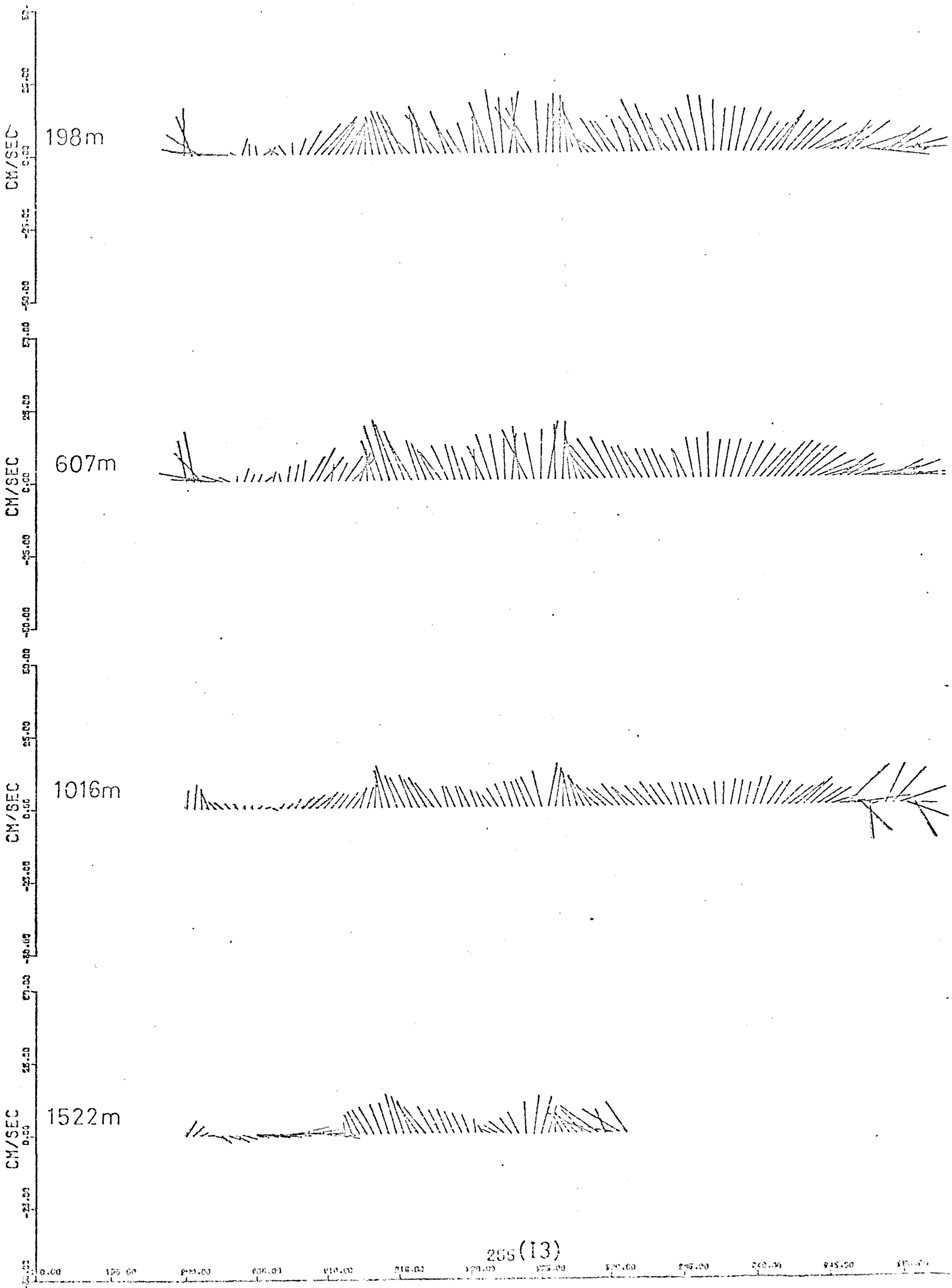
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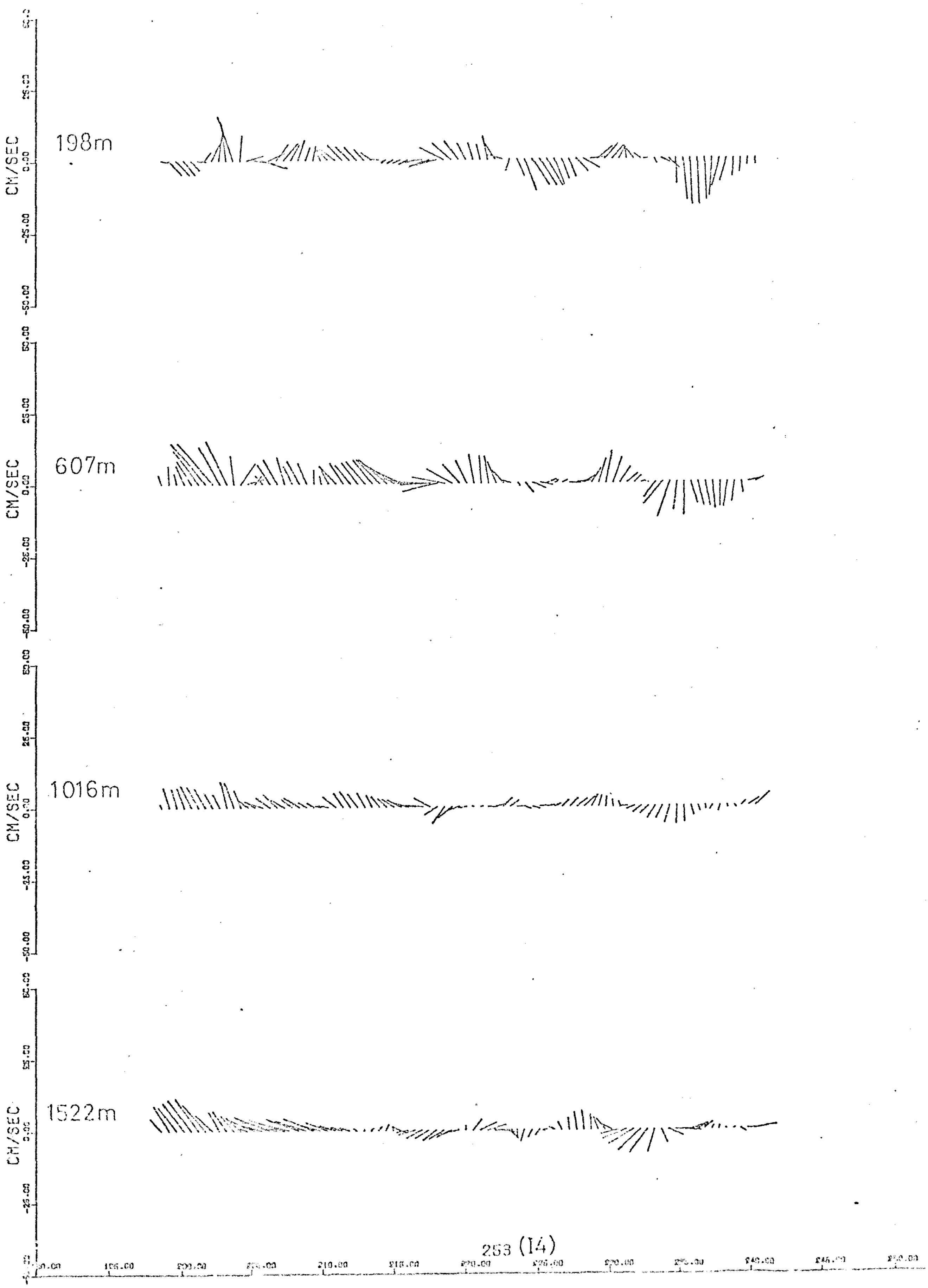
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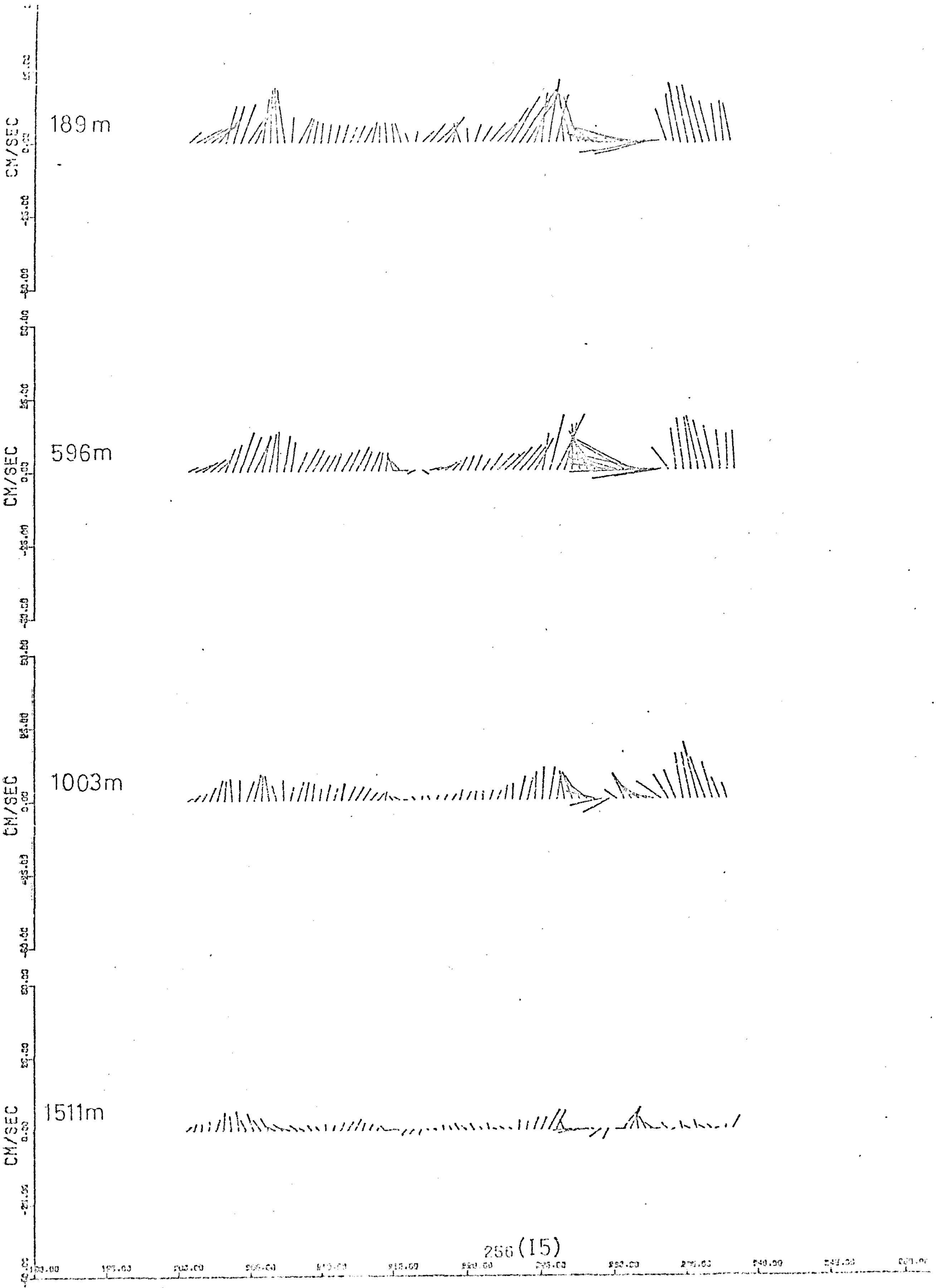
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