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RADAR MEASUREMENT OF ICE DRIFT IN ROBESON CHANNEL, 1972

by

John E. Keys, Moira Dunbar, D.J. Finlayson and J.W. Moffat

PROJECT NO.
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ABSTRACT (U)

This report describes a technique used for measuring ice drift in Robeson Channel, Ellesmere Island, using an X-band radar mounted on a cliff to track transponders placed on the ice. The transponder stations were equipped with wind recorders and, when possible, current meters. The PPI was read manually every hour and a film record made, one shot being taken per minute. The manual readings were fed into a computer and a plot generated in the field. The film record was later digitized and corrected plots made. These are included in the report, together with samples of the field plots.

Analysis of the data has not yet reached the reporting stage, but a few preliminary findings are given.

RÉSUMÉ (U)

Ce rapport décrit la technique utiliseé pour mesurer la dérive de la glace dans le chenal Robeson, situé au nord-est de l'ile Ellesmere, à l'aide d'un radar operant dans la bande X, installé sur une falaise et pouvant suivre les émetteur-récepteurs asservis par impulsion installés sur les floes. En plus d'un émetteur-récepteur, les stations étaient aussi équipées d'un anémometre enregistreur et, lorsque possible, d'un enregistreur de courants marins.

L'écran de radar fut lu visuellement à chaque heure, ainsi qu'à chaque minute par un procéde photographique. Les lectures visuelles furent introduites dans un calculateur en vue d'obtenir des graphiques préliminaires immédiatement accessibles sur place. Les lectures photographiques furent par la suite digitalisées et corrigées pour être introduites dans l'ordinateur en vue d'obtenir des graphiques précis. Ceux-ci ainsi que quelques exemples des graphiques préliminaires sont inclus dans ce rapport.

L'analyse des données n'est pas encore rendu à un stage assez avancé pour pouvoir produire un rapport complet, mais les quelques résultats preliminaires, pouvant être avancés à ce stage-ci, sont inclus dans ce rapport.

RADAR MEASUREMENT OF ICE DRIFT IN ROBESON CHANNEL, 1972

Robeson Channel is the northernmost part of Nares Strait, which separates Greenland from Ellesmere Island and which is one of the main passages connecting the Arctic Ocean with the Atlantic by way of the Canadian Arctic Archipelago - the only such passage that provides a direct route, without the complication of interconnecting channels. It is thus a factor in the water and heat exchange between the arctic and temperate regions, as well as a potential navigation route for surface and sub-surface vessels. For these reasons the strait, and Robeson Channel in particular, was chosen as the site of a study of ice drift in restricted channels. This report presents some of the basic data obtained in the field season 1972, analysis of which is now in hand. A second full data-gathering season is planned for July-August 1974.

Robeson Channel is 65 km long and from 20 to 35 km wide, flanked by bold cliffs on both sides. It is fairly deep, as is the whole of Nares Strait, with depths between 350 and 750 m and steep-to coasts. It was known from ships' records and other historical observations to be an area of heavy ice with a predominantly southerly drift pattern and strong tidal currents. Very little oceanographic information was available for this part of Nares Strait before the start of the operation, and the nearest weather station, Alert, though close in distance, has limited relevance because of the importance of local topographic effects. The channel is oriented northeast-southwest.

METHOD

Ice movement was tracked by means of a radar set up on the coast. This method has been successfully used in Japan on a much larger scale to track ice movement off the coast of Hokkaido by (Tabata et al (1)) and also by the Zhmurko in the Gulf of Tartary (2). Current and wind measurements were made from the ice for correlation with the ice drift data.

Instrumentation

Radar: The radar was Foruno Model FRA 10, which transmits a

5-kW pulse at a frequency of 9375 MHz. It is an inexpensive radar designed for use in small vessels and with a few modifications it proved adequate for the purpose. It has a maximum range of 20 nautical miles. The radar was equipped with a 16-mm camera which photographed the PPI* every minute.

Current meters: The current meters were Braincon Model 381, set to integrate the current over 20-minute periods, providing three measurements per hour. These were chosen as the result of discussion with many organizations involved in current measurements, as being considered the most reliable instrument of those readily available.

Wind recorders: The wind recorders were Braincon Model 2381, and are essentially the same as the Braincon current meters. Since they were to be installed on moving floes, it was necessary to have an instrument that recorded azimuth, which it does by photographing a magnetic compass.

OPERATIONS

Radar operations

In 1971 a camp was established south of Lincoln Bay and the radar installed in a hut close by, about 600 m from the cliff edge, at an elevation of about 400 m above sea level. It was found that interference occurred between the direct signal from antenna to target and a second signal from antenna to cliff edge to target. In addition it was found impossible to identify individual features in the ice pattern for long enough periods to use them for tracking. Corner reflectors were tried but failed to show up against the general ice clutter. The interference problem was resolved in 1972 by moving the radar to another site which was only about 4 m from the cliff edge; a small amount of height was sacrificed, as the new site was only 345 m above sea level, but the advantages of being closer to the cliff more than compensated for this. To solve the tracking problem transponders were used to identify the floes selected. These were Alpine Model 4270 transponders with a power output of 400 W.

Ice stations

The ice stations consisted of instrumented rafts which were set out by helicopter, an Alouette II with a lift capacity of 590 kg (1,300 lbs). Each raft carried a radar transponder, a wind recorder, and, where possible, two recording current meters. A VHF radio beacon was included to aid in recovery of the raft. A wind recorder was placed 3 m above the ice surface, and the current meters 5 and 15 m below the water surface. The rafts consisted of a simple plywood platform, 1.68 m (8 ft) square, mounted on four empty 200-litre (45-gallon) fuel drums, with a hole in the centre for lowering the current meters. For protection against ice pressure they were placed on puddles in multi-year floes in which thaw holes were sought for installation of the current meters. The technique is described in detail by Finlayson (3).

The stumbling-block in this system proved to be the reliance on finding thaw-holes suitably placed. Although there was no shortage of

* Plan Position Indicator

holes, nearly all of them were in first-year ice, often at the edges of old floes but seldom in them. To what extent this was due to the unusually cold summer of 1972 is not clear, but it may be normal. The alternative of using explosives to blow holes in the ice was tried but has the disadvantage of necessitating extra helicopter trips and of being time-consuming. As a result of this only the first four stations, maintained simultaneously from about 10 to 29 July, were equipped with current meters. For all but the last two days of this period the ice was shorefast. After this the stations moved so fast and had to be replaced so often that it was found necessary to discontinue using current meters rather than have long periods with no stations on the ice.

Between 29 July and 30 August a further 23 stations equipped with wind recorder and transponder only were tracked, making a total of 27, for an average tracking time of about 40 hours. Usually two stations were on the ice at a time. Only one was lost (station 5.3, Figs. 5 and 14), when a rather small floe broke up in a high wind and all the equipment was destroyed; all the others (26 in all) were successfully recovered by helicopter. Almost complete continuity of station coverage was achieved, except for the five days from 11 to 15 August, when helicopter unserviceability put a stop to flying operations. During this period the radar continued to operate, and it is hoped that at least some measurement of drift will be possible from the film record of the ice itself.

Spring current measurements

Additional oceanographic information was collected in the spring of 1971 and 1972. In each year an array of current meters was installed across the channel and over a month of recorded data was obtained. In 1972 recording thermographs were added to the instrument package, and standard oceanographic measurements were made when recovering the stations.

In 1971 a month's tidal observations were obtained at Lincoln Bay.

Station numbering

The transponders used return two signals for each pulse received from the radar; the first represents the transponder's position and the second has an adjustable delay of from 3 to 18 microseconds (150 to 900 metres) which is used for identification. The delays of the four transponders were set at 5, 6, 7 and 8 microseconds respectively and the instruments were correspondingly numbered.

The stations set on the ice were assigned the number of the transponder followed by the number of times that instrument had been set out. For example, Station 7.4 represents the fourth time that the transponder with 7 microseconds delay had been installed on the ice.

Transponder 5 was lost after three stations, and 8 did not function well, so most of the stations have the first number of either 6 or 7.

Drift data recording

A 16-mm cine-camera, mounted on the radar, photographed the PPI display once every minute. The resulting film provided the main data-source. In addition, hourly readings of the bearing and range to the transponders on the ice were taken manually. These readings were then fed into a Hewlett Packard 9100B calculator, where a programme calculated the average hourly speed, direction and distance of travel; the results were both printed out and plotted (Figs. 2 - 5). This preliminary field analysis served a number of purposes. The output plots showed which areas of the channel had been investigated and, hence, which areas needed more study. The plots could also be extrapolated when a transponder disappeared from the PPI to indicate where the helicopter recovery party should search. They also showed up erroneous readings, providing a check on the human failings of the watchkeepers.

Notes were made hourly in the log book recording the estimated wind at the radar site, apparent direction of wind in the channel, and sea surface state when open water was visible. Surface winds were recorded continuously at the base camp. Whenever the visibility was more than 3-5 km, a series of five photographs were taken hourly to provide a panorama of the ice in the channel.

Data processing

For analysis, the 16-mm film was projected frame by frame onto a Hewlett-Packard digitizer. The transponder positions were digitized and recorded on magnetic tape. Using this tape, a computer then generated plots of the motion of each transponder. The details of the digitizing technique are described in Keys (4) and those of the computer programming in Moffat (5). The wind and current film data have been similarly digitized.

ICE DRIFT PLOTS

Figs. 2 to 5 are samples of the plots made in the field using the HP 9100B calculator. Figs. 6 to 32 are the computer-generated plots derived from the digitized film data. On all these the lines running from the radar position (centre) represent the approximate limit of radar visibility (not always, as can be seen for instance in Fig. 2, the actual limit). The lines on the right represent the coast of Greenland as drawn by joining a number of points plotted from the PPI.

Field plots

In the field plots (Figs. 2 to 5) times are GMT uncorrected and the range rings are at 5-nautical-mile intervals.

These plots are included as samples of the field data, and also because they show relationships between stations. Those in Fig. 2 (6.11 and 7.7) were separated in time by nearly 24 hours, but the others are all at least to some extent simultaneous. Fig. 3 shows two stations of which one (7.8) moved considerably faster and straighter than the other, Fig. 4 two whose tracks crossed each other, while Fig. 5 illustrates the only period of persistent southerly winds, during which the floes turned up-channel. Station 6.12 (Fig. 3) has been annotated to show the kind of differences that occurred between the field plot and the film plot. The small dots represent the latter, and some are joined to the corresponding points in the field plot for added clarity. The large jog towards the radar on 28 August was recognized in the field as an observer's error, and was easily corrected from the film. The remaining rather large discrepancies between the two plots are due largely to parallax problems in reading directly from the radar. This situation has been improved for the 1974 season by the addition of a variable range ring.

The track of Station 8.2 on Fig. 5 has three dashed sections which represent periods during which the transponder was not visible. In the computer-generated plots such gaps have been filled by linear interpolation except in one case (Station 7.6) where the gap was too large.

Computer-generated plots

The plots of the digitized data (Figs. 6 to 32) have corrected GMT time values. The range rings have been changed from nautical miles to kilometres, which accounts for a number of apparent discrepancies, the most obvious of which is the position of the Greenland coast in relation to the rings. The fact that Station 8.1 (Fig. 9) appears to cross the coast of Greenland should not cause too much concern; it is almost certainly due to a reading error on the PPI when plotting the coastline rather than to error in digitizing the film.

A shortcoming of the computer plots is that the "start" symbol does not show up clearly in cases where a time symbol follows closely. It is therefore well to point out that all the stations moved down-channel except those in Figs. 13-18, which represent the only period of persistent southerly winds (from 3 to 10 August).

The long gap in the track of Station 7.6 (Fig. 27) is due to the fact that because of a change in the scale of the film record in this section it has not been digitized.

PRELIMINARY RESULTS

The data described are in process of detailed analysis which will be the subject of later reports. It is, however, possible to mention here a few deductions which can be made from the plots themselves and from a cursory examination of the wind and tidal data.

The predominant drift throughout the operation was, as expected, southwest, or down-channel. This was the result of a combination of mainly northerly winds and a predominantly down-channel current pattern. The currents, which appear to play an important part in the ice drift, are largely tidal, but seem to run much more strongly on the flood tide, which is southwesterly, than on the ebb. Thus in periods of dead calm, the ice moved steadily southwest, making only a little northerly progress on the ebb tide as compared to a great deal of southerly movement on the flood.

This is illustrated in Fig. 2, which covers a period of very light winds. The approximate times of high (H) and low (L) tide have been marked beside the tracks and reveal a pronounced relationship between tidal phase and drift speed, the drift slowing down, though not in most cases reversing, during the ebb tide. Station 6.11 did change direction on two occasions (Fig. 28 for the corrected drift) but 7.7 did not, the northerly move at 1000 on 27 August shown in Fig. 2 being apparently erroneous (see Fig. 29). It should be noted that these two stations are actually a day apart.

In Fig. 4, on the other hand, there is very little apparent correlation between tidal cycle and the drift of the two stations, both of which wandered aimlessly in a restricted area for nearly 12 hours between 2300 on 19 August and 1000 on 20 August, and then moved on rather slowly, picking up to a more typical rhythm as they moved down-channel. It would be pointless to embark on a detailed manual analysis at this stage, but it is interesting to note that the wind data from Station 6.8 show a change from down-channel to up-channel winds at 1940 on 19 August and that they continued in this direction at speeds ranging from about 2 m/sec up to 7 m/sec and down again, until 2200 on 20 August, at which time the down-channel winds resumed. Thus the stations were apparently responding to opposing wind and tidal influences during part of the drift. The wind was sufficiently strong to interrupt the tidal drift but not to reverse it.

During the one period of strong and persistent southerly winds that we experienced (Figs. 5, 13-18), the drift direction was reversed, but the effect of the wind appeared to be modified by the opposing force of the current. Although the winds reached gale force at times, the northerly drift was slow and uncertain in direction compared to the southerly drift observed with northerly winds. Thus there seems to be little doubt that the overall drift is southward.

Net drift speeds (measured from beginning to end of drift) varied from .06 to .61 m/sec (.11 to 1.19 knots) and average hourly speeds from .25 to .63 m/sec (.48 to 1.22) knots). The highest hourly speeds, as high as 1 - 1.30 m/sec (2 - 2.50 knots), were usually measured towards the southwest end of the channel, where many of the stations seemed to accelerate. There also seemed to be a tendency in the case of simultaneous drifts for the stations on the Greenland side of the channel to have higher speeds than those on the west side.

All these observations are preliminary and tentative. The drift figures especially must be regarded as provisional only, as they are based on the field data plots, which have been shown to be subject to considerable error, owing partly to human frailty but mainly to the virtual impossibility of getting an accurate manual fix from the PPI scope.

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3. Finlayson, D.J., (1972). Techniques for deploying surface and submerged recording instruments in the waters of the Canadian Arctic Archipelago. DREO Tech. Note 72-29.

4. Keys, John E., 1973. Data reduction system for 16 mm film records. DREO Tech. Note 73-14.

5. Moffat, John W. (in press). Radar position data reduction programs for the Xerox Sigma 9. DREO Tech. Note 74-

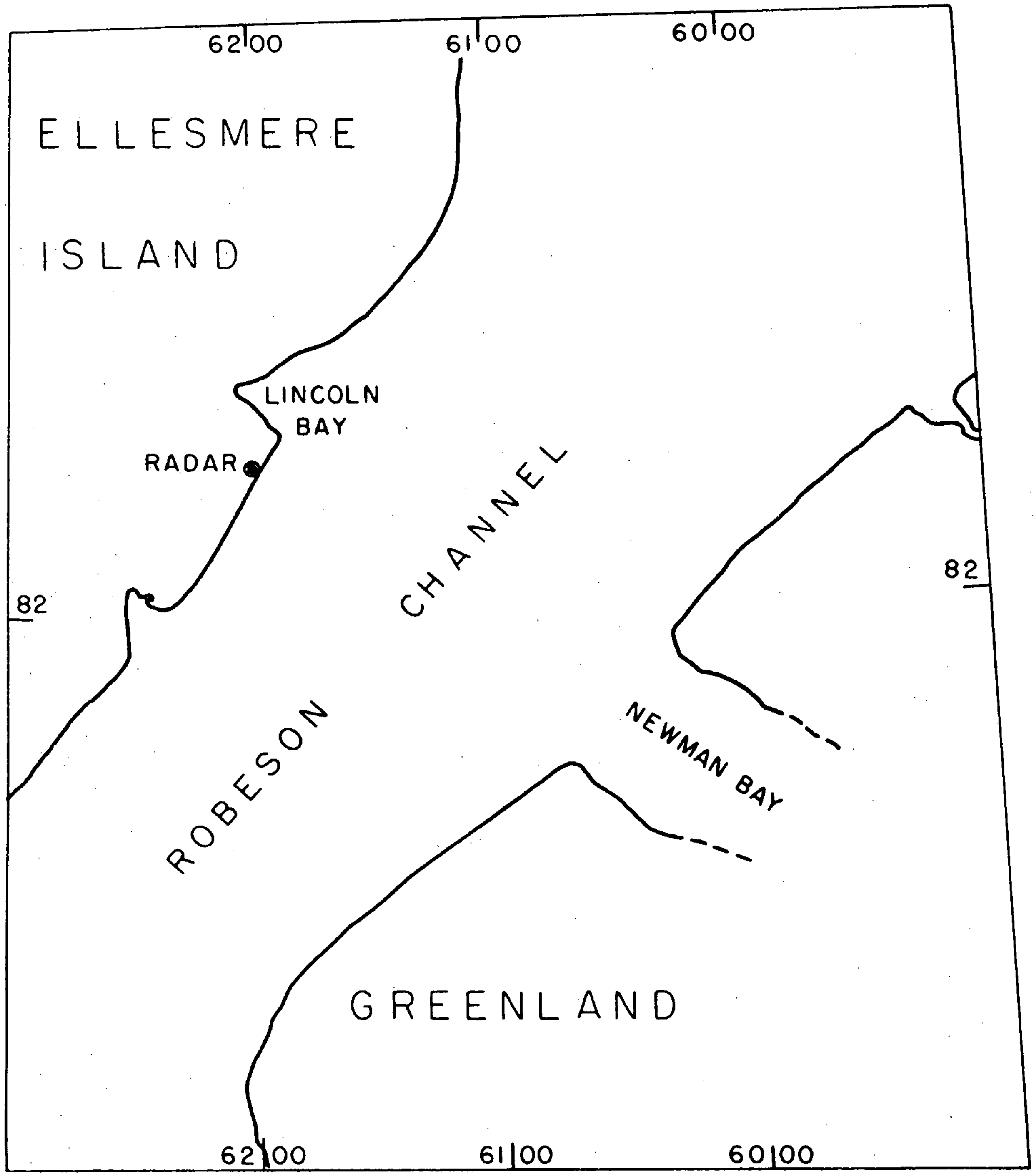

Fig. 1. Map of Robeson Channel, showing radar site.

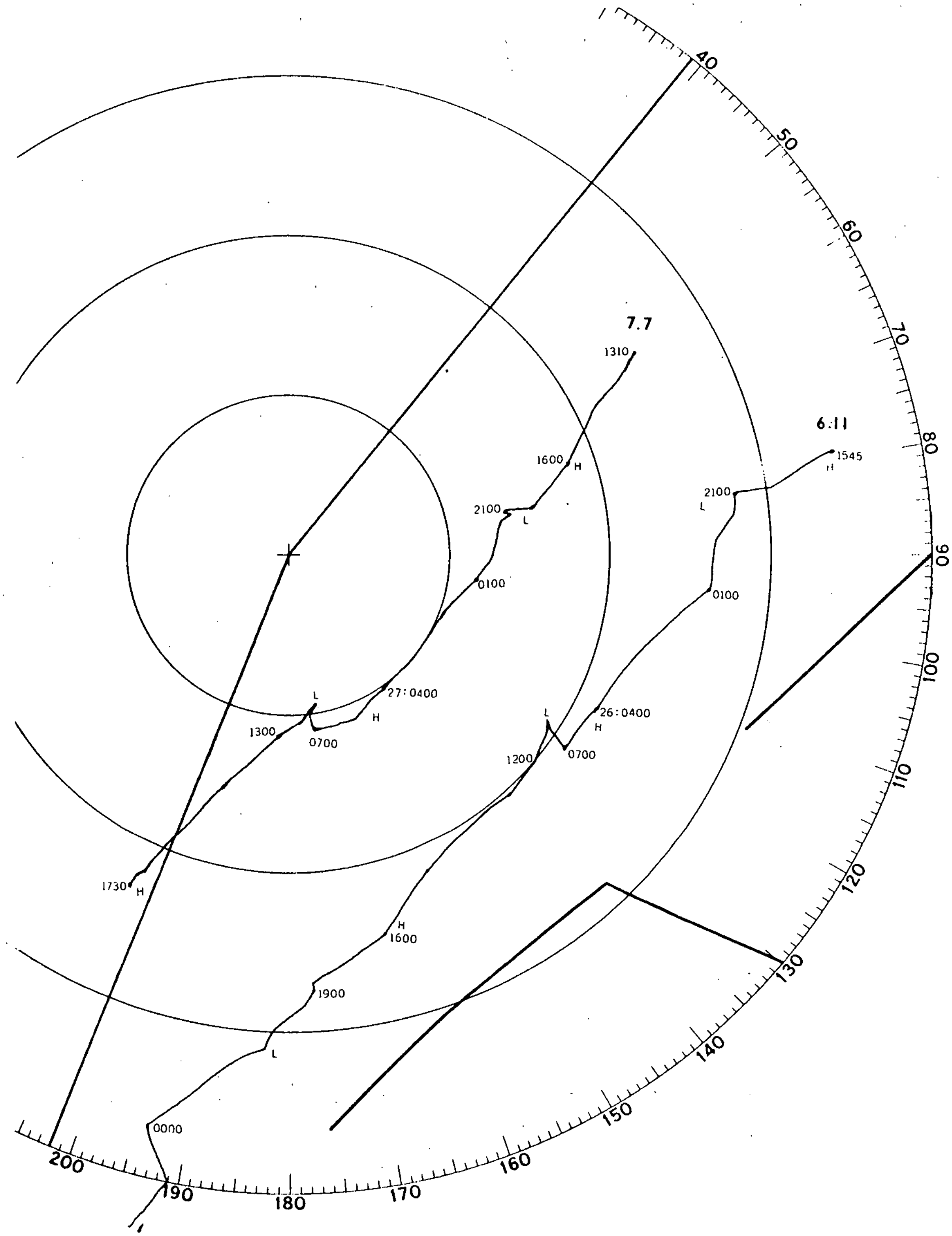

Fig. 2. Sample field plot
Station 6.11: 25 Aug 1545Z - 27 Aug 0200Z
Station 7.7: 26 Aug 1300Z - 27 Aug 1730Z

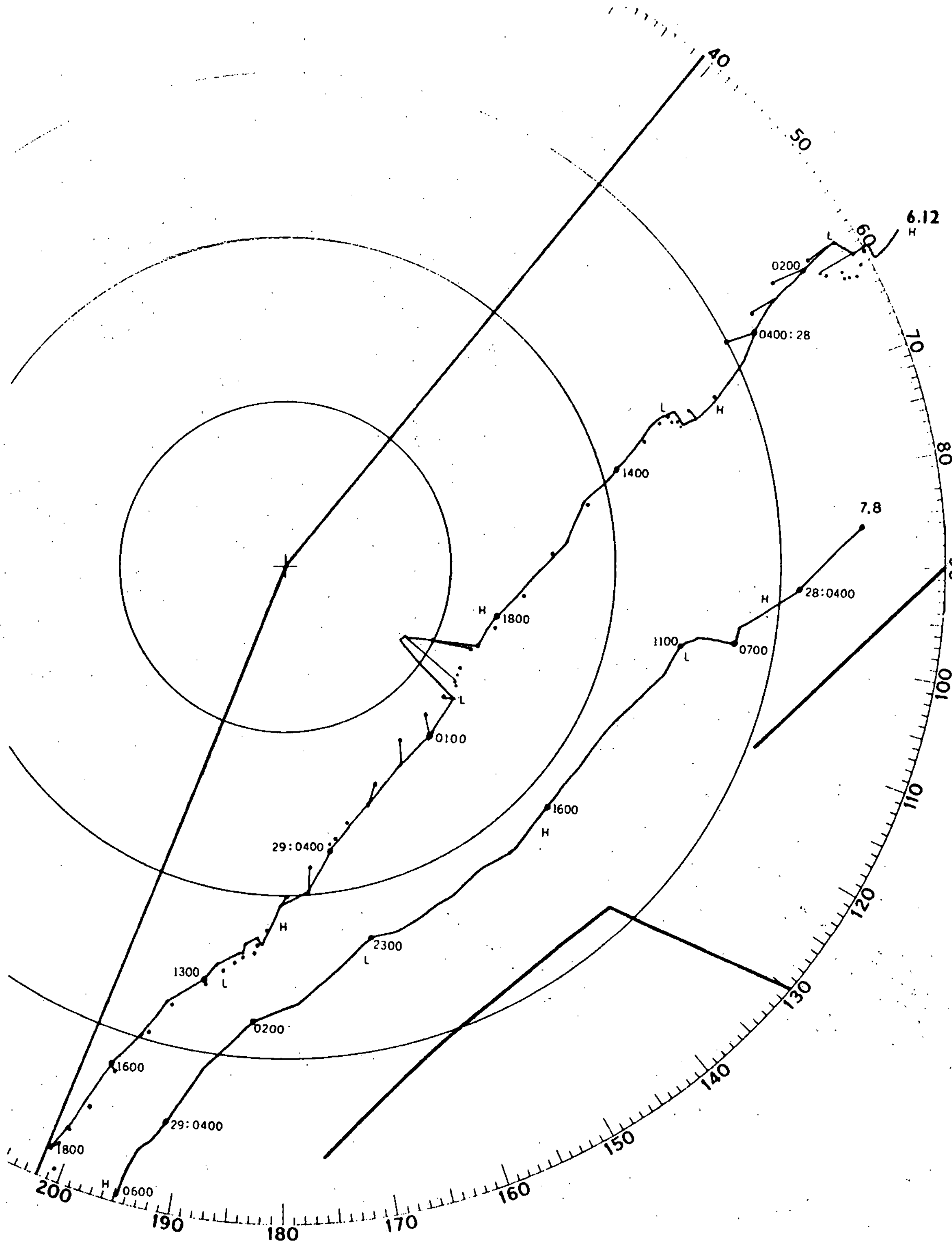

Fig. 3. Sample field plot
Station 6.12: 27 Aug 1730Z - 29 Aug 1800Z
Station 7.8: 28 Aug 0300Z - 29 Aug 0600Z

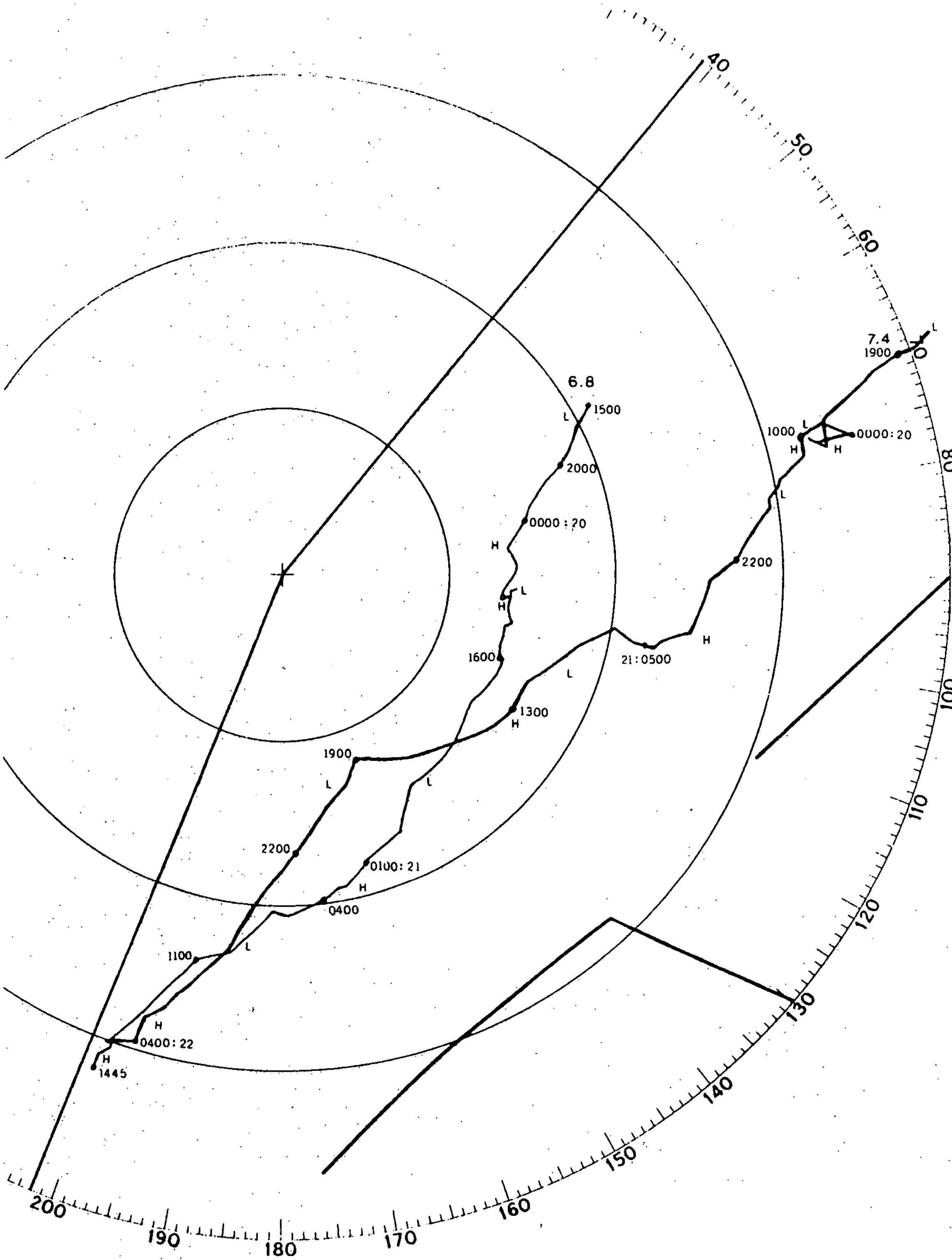

Fig. 4. Sample field plot
Station 6.8: 19 Aug 1500Z - 21 Aug 1445Z
Station 7.4: 19 Aug 1700Z - 22 Aug 0500Z

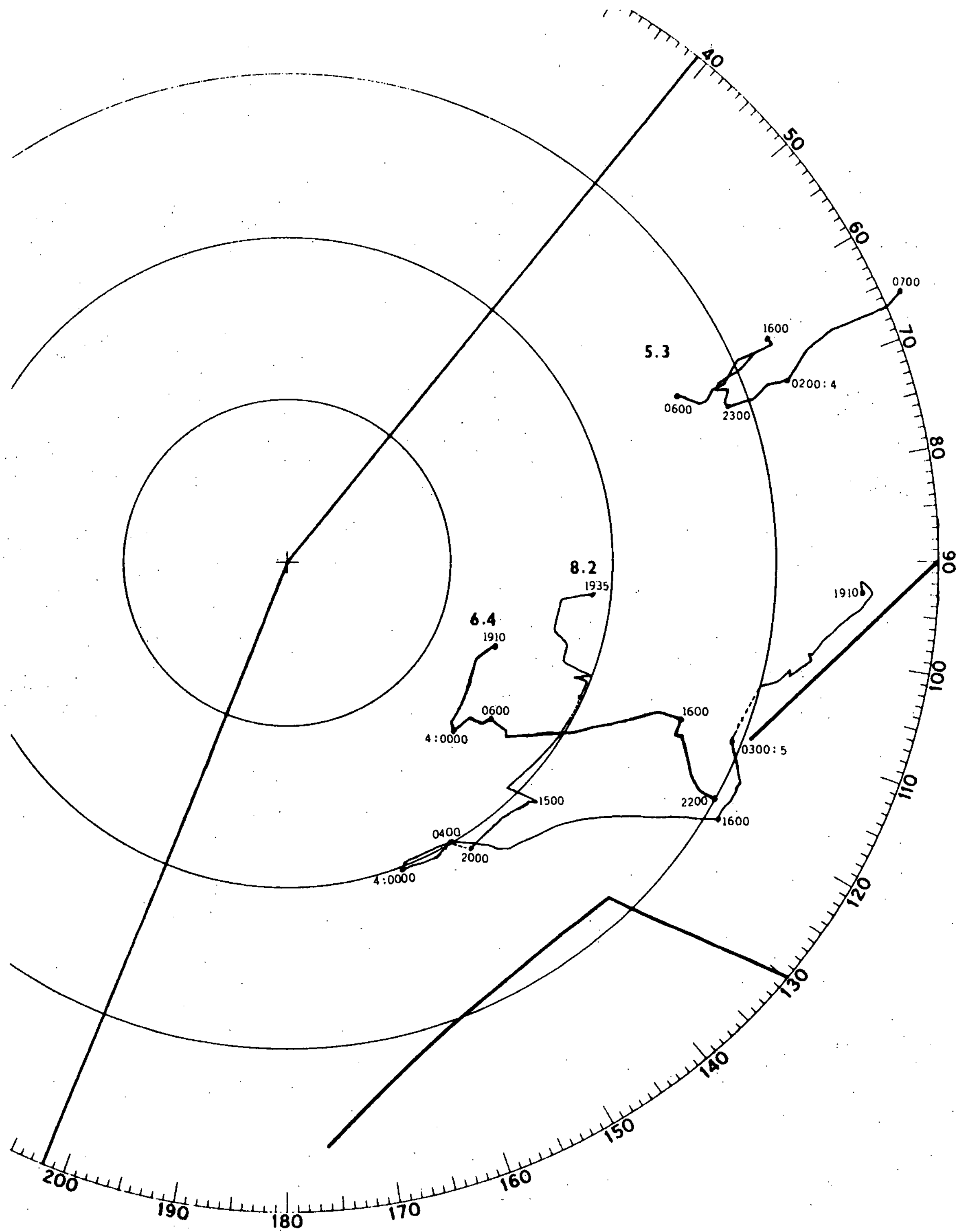

Fig. 5. Sample field plot
Station 5.3: 3 Aug 0500Z - 4 Aug 0700Z
Station 6.4: 3 Aug 1910Z - 4 Aug 2300Z
Station 8.2: 2 Aug 1935Z - 5 Aug 1910Z

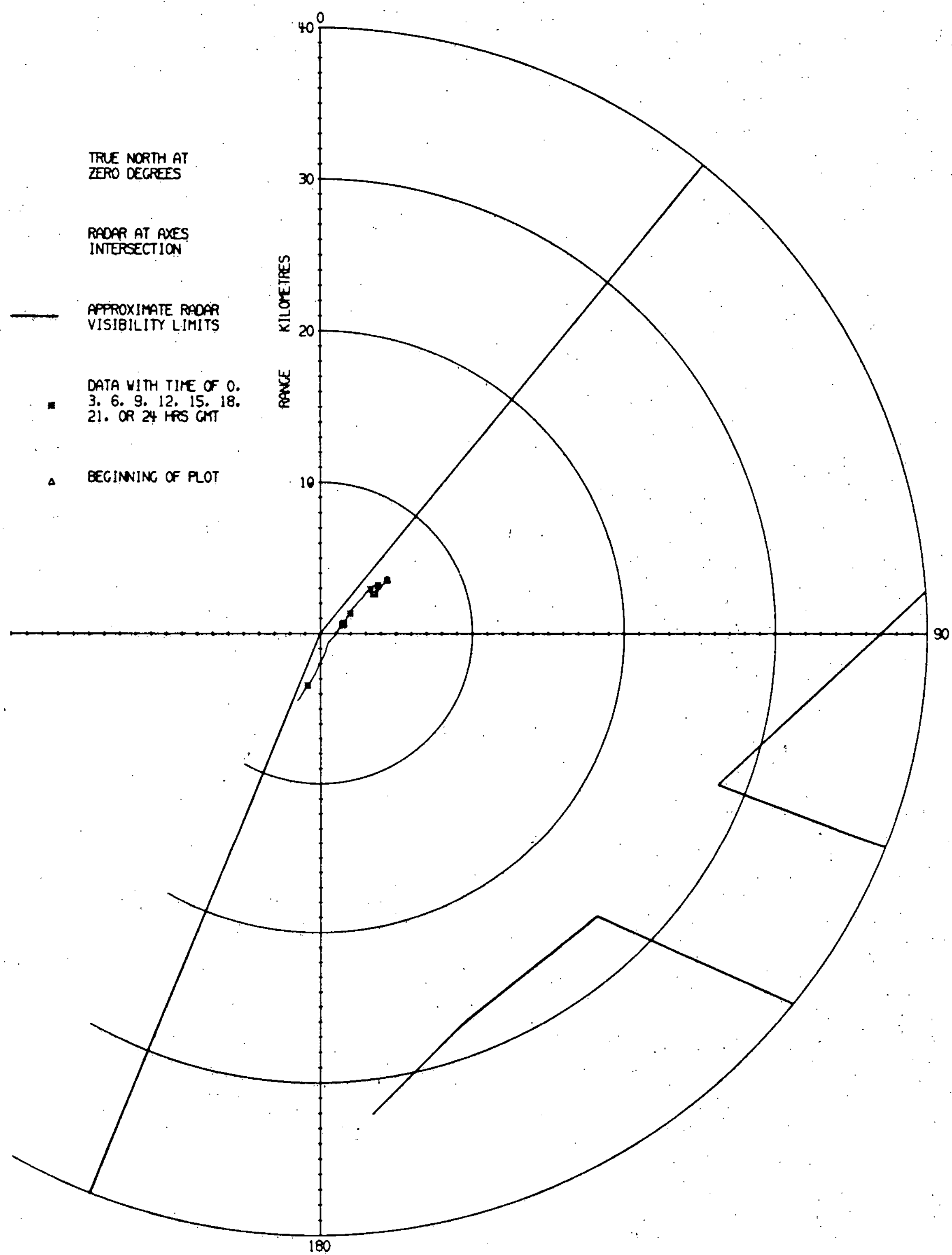

Fig. 6. *Station 5.1*
Start:27 July 2251Z *Finish: 29 July 0332Z*

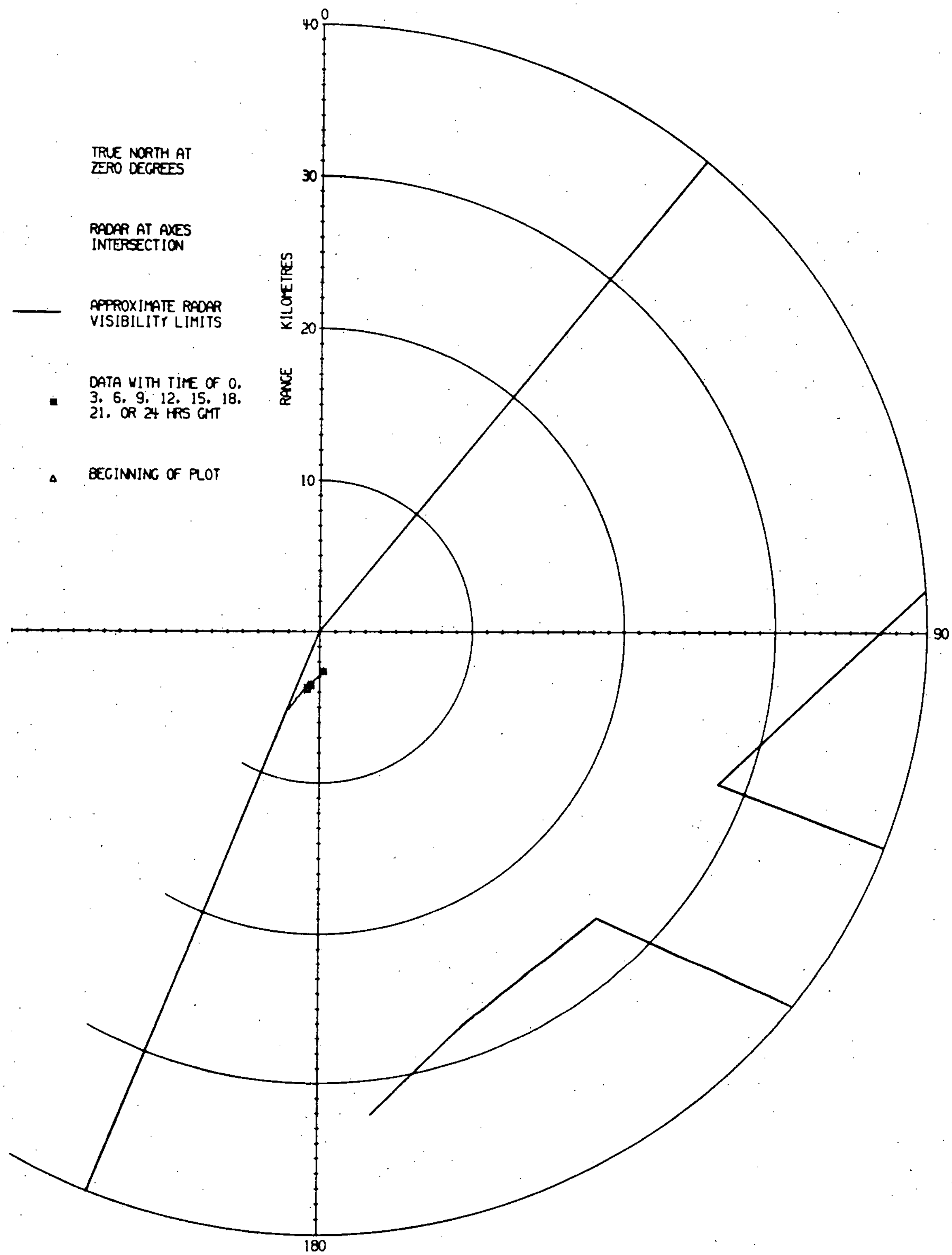

Fig. 7. *Station 6.1*
Start: 27 July 2351Z Finish: 28 July 1418Z

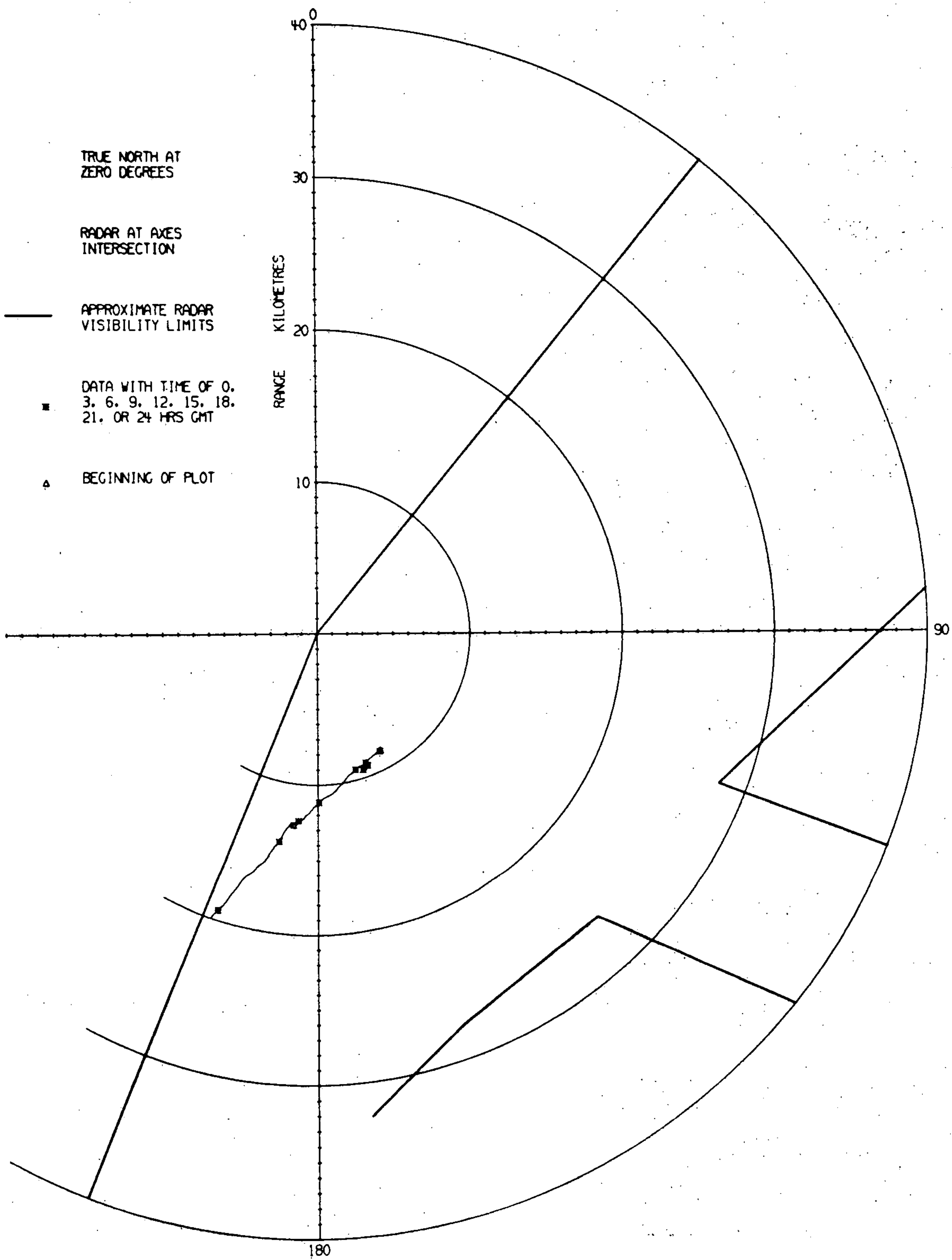

Fig. 8. *Station 7.1*
Start: 27 July 2251Z Finish: 29 July 0323Z

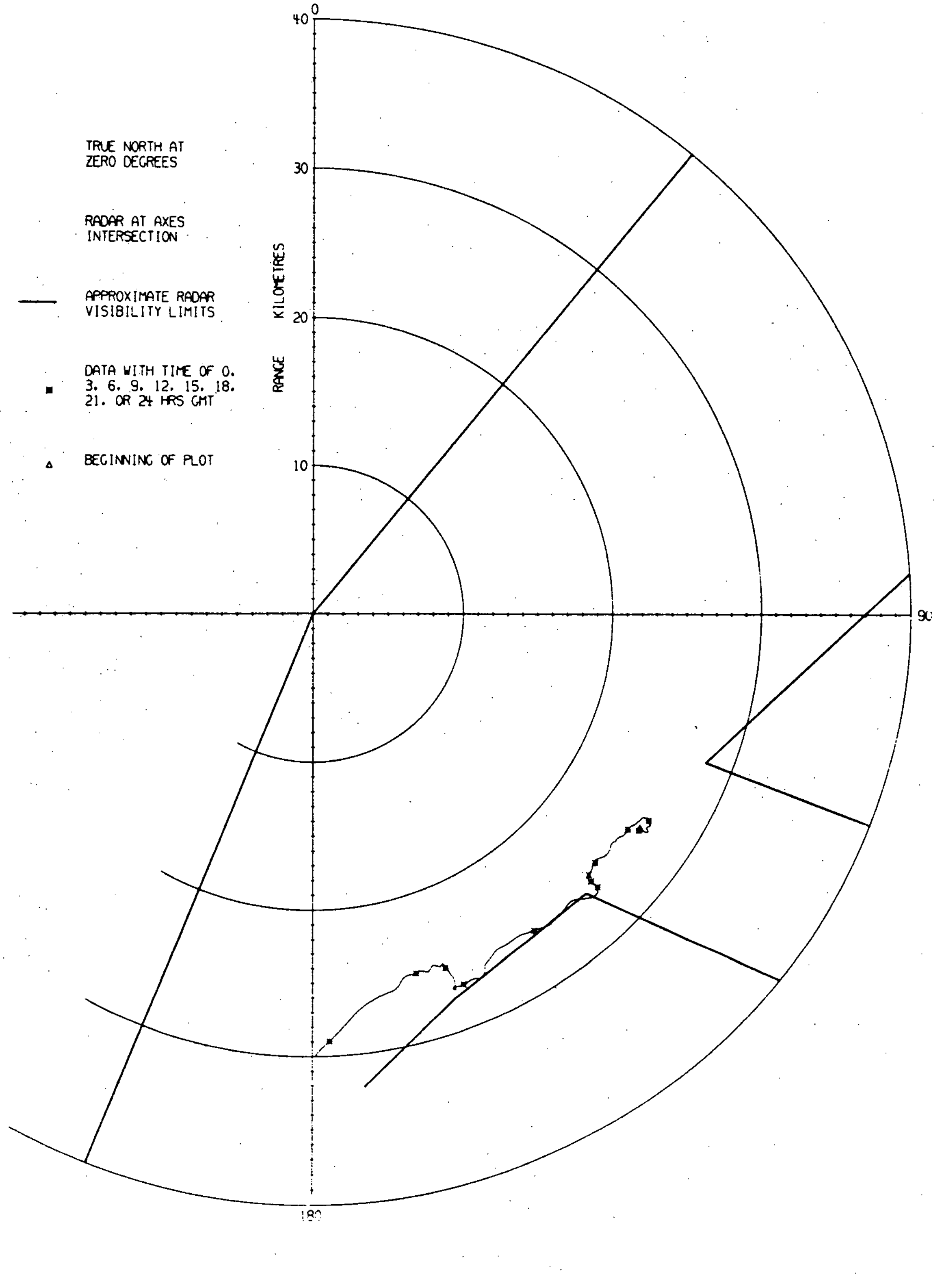

Fig. 9. *Station 8.1*
Start: 28 July 0351Z Finish: 29 July 1551Z

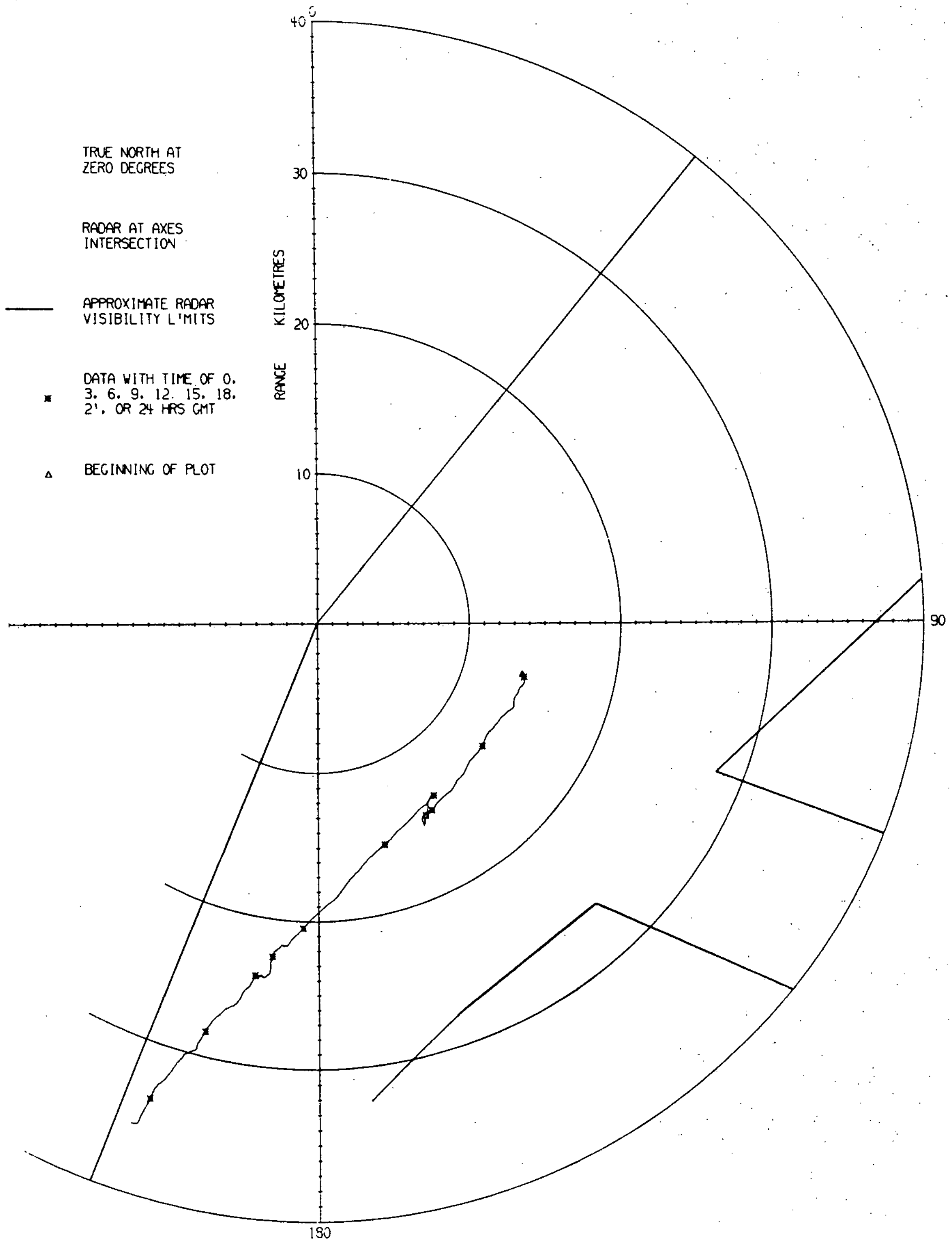

Fig. 10. *Station 6.2*
Start: 29 July 2349Z *Finish: 31 July 0653Z*

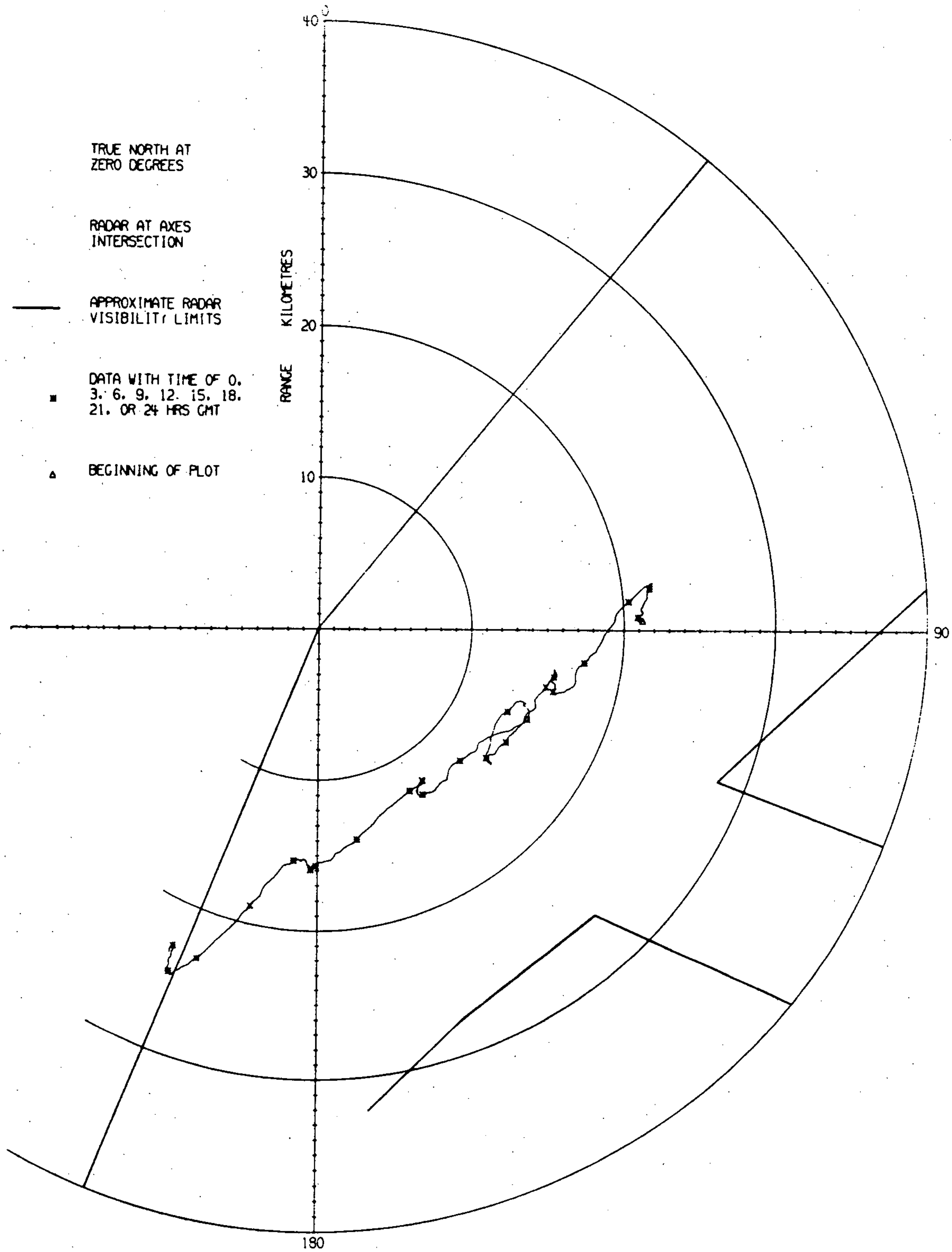

Fig. 11. Station 6.3
Start: 31 July 0742Z Finish: 3 August 0349Z

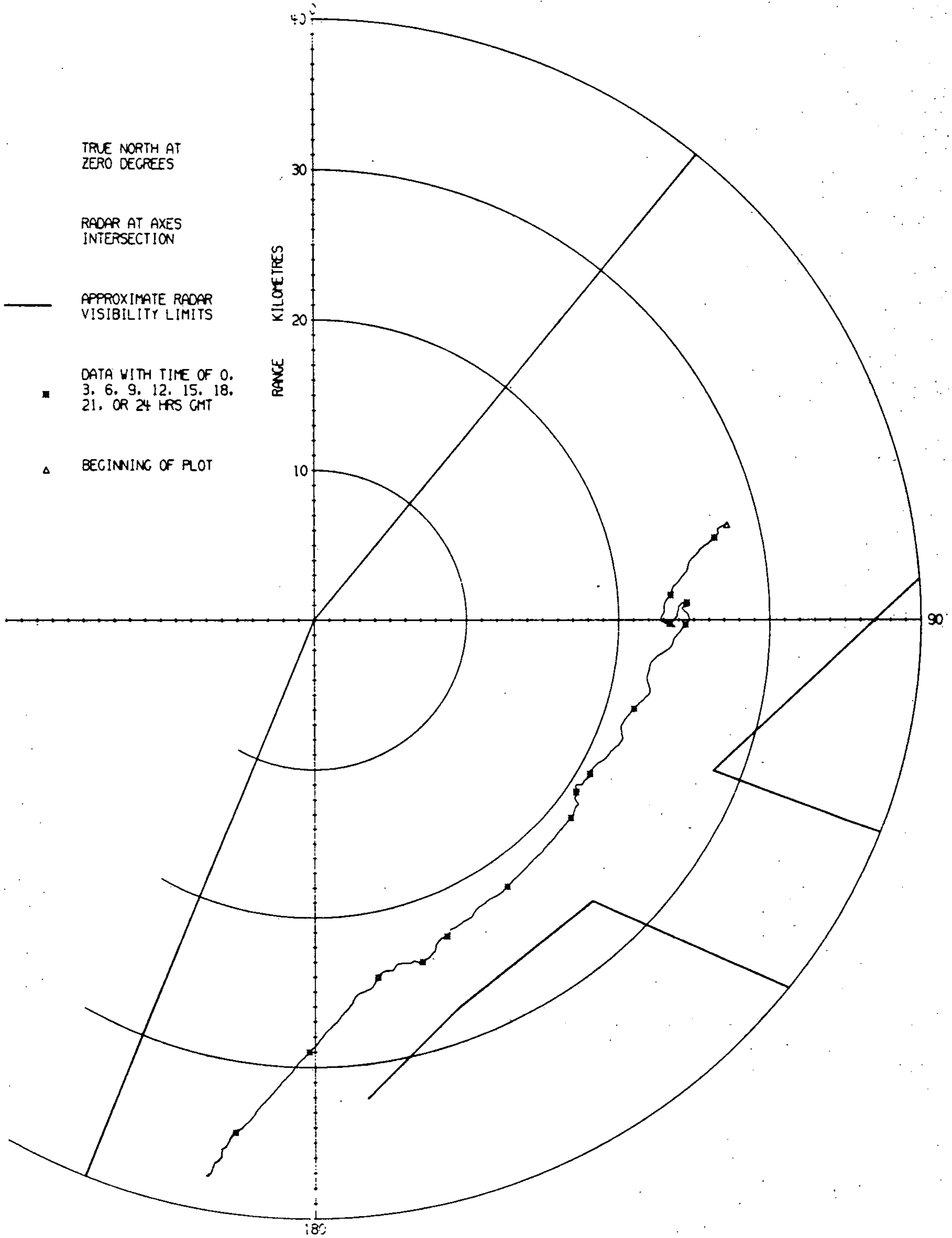

Fig. 12. *Station 5.2*
Start: 1 August 0151Z *Finish: 2 August 2340Z*

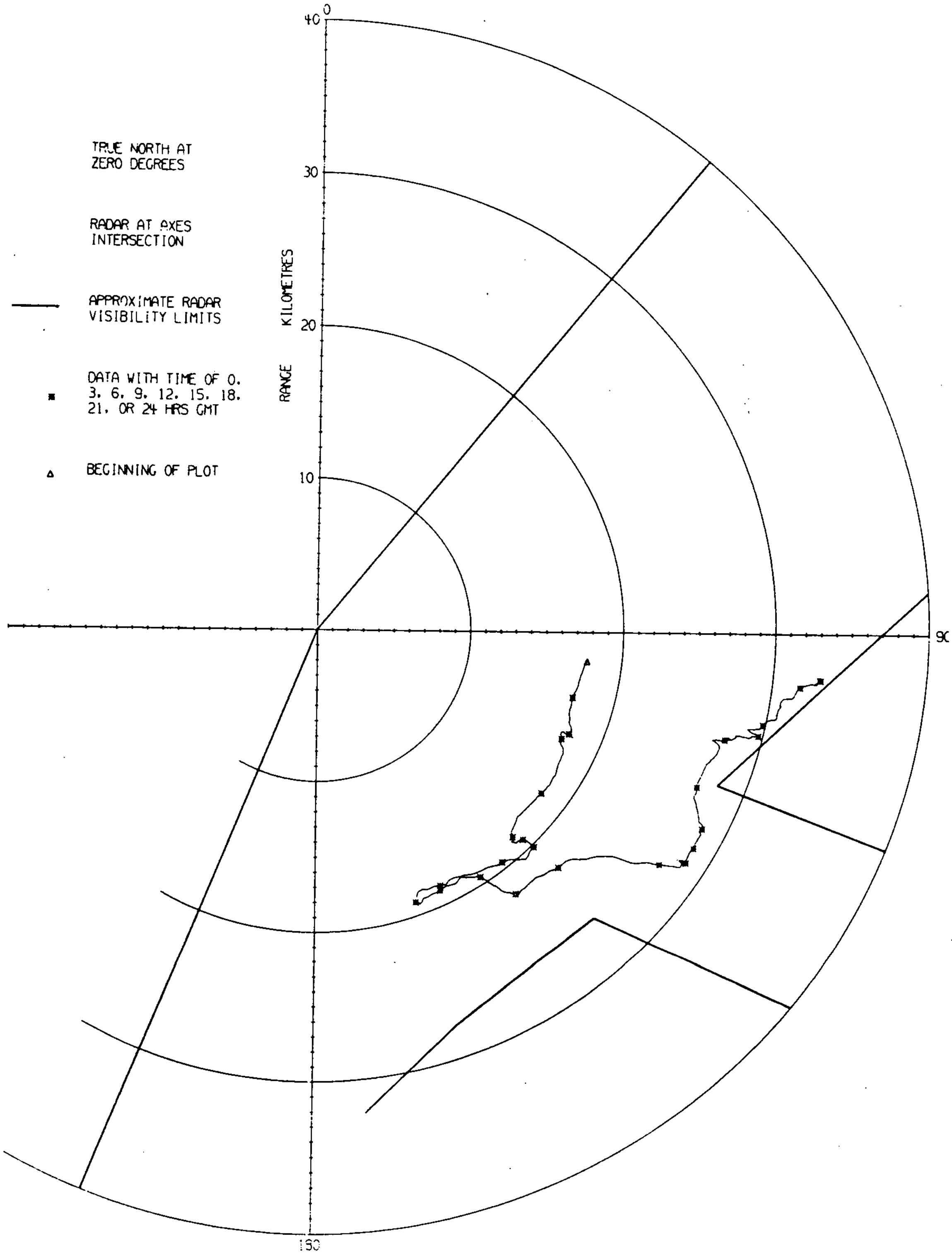

Fig. 13. *Station 8.2*
Start: 2 August 1921Z *Finish: 5 August 1849Z*

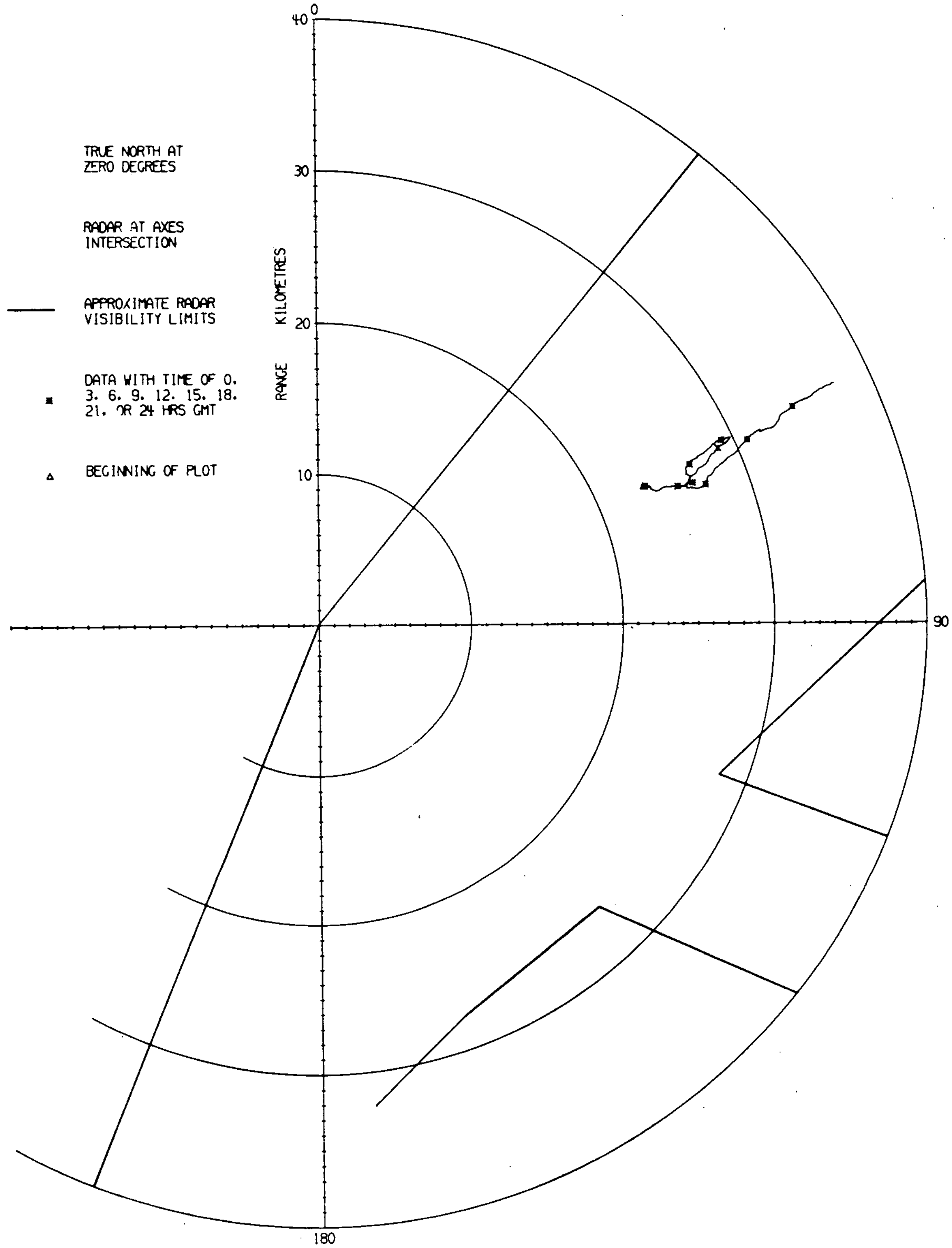

Fig. 14. Station 5.3
Start: 3 August 0541Z Finish: 4 August 0801Z

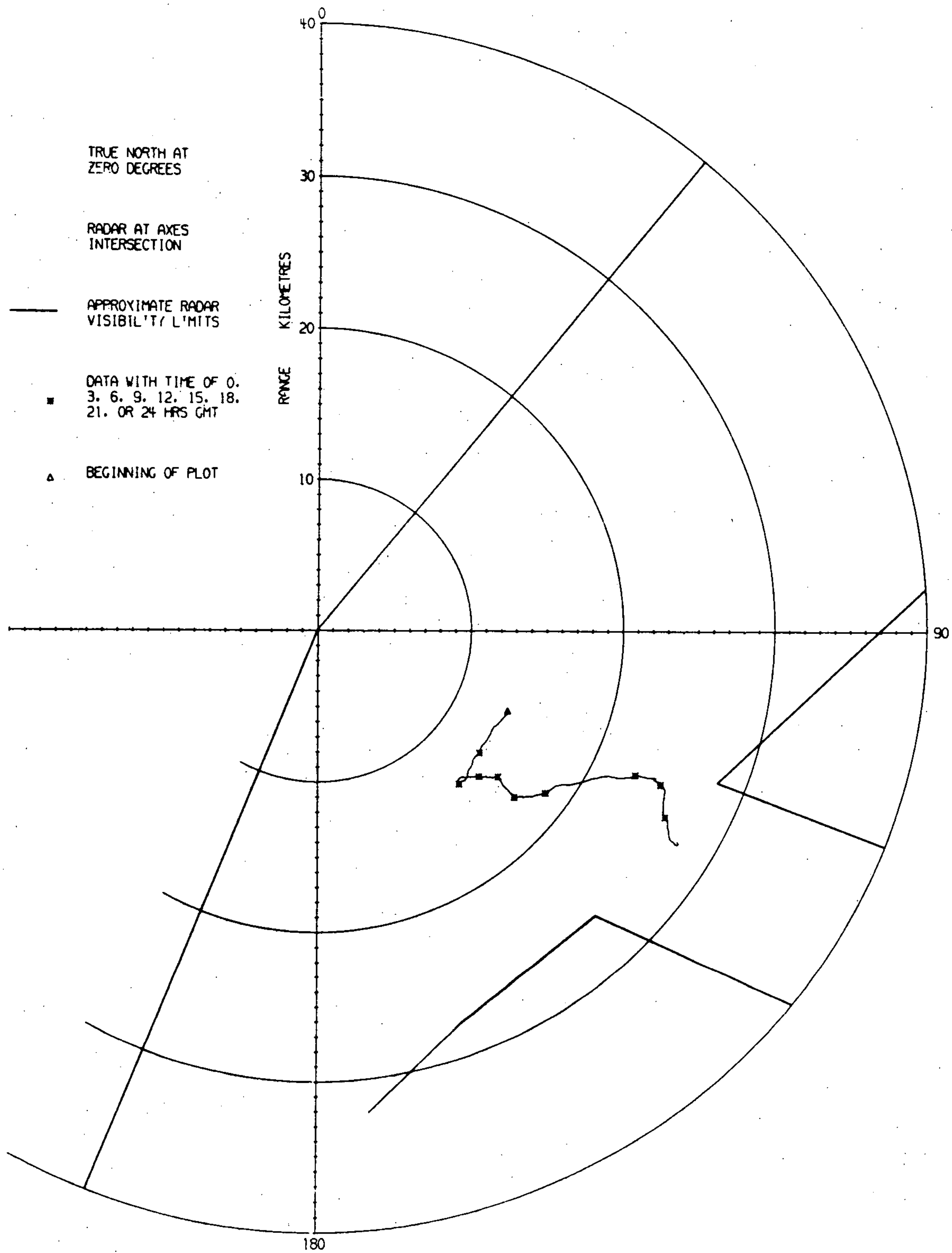

Fig. 15. Station 6.4
Start: 3 August 1854Z Finish: 4 August 2325Z

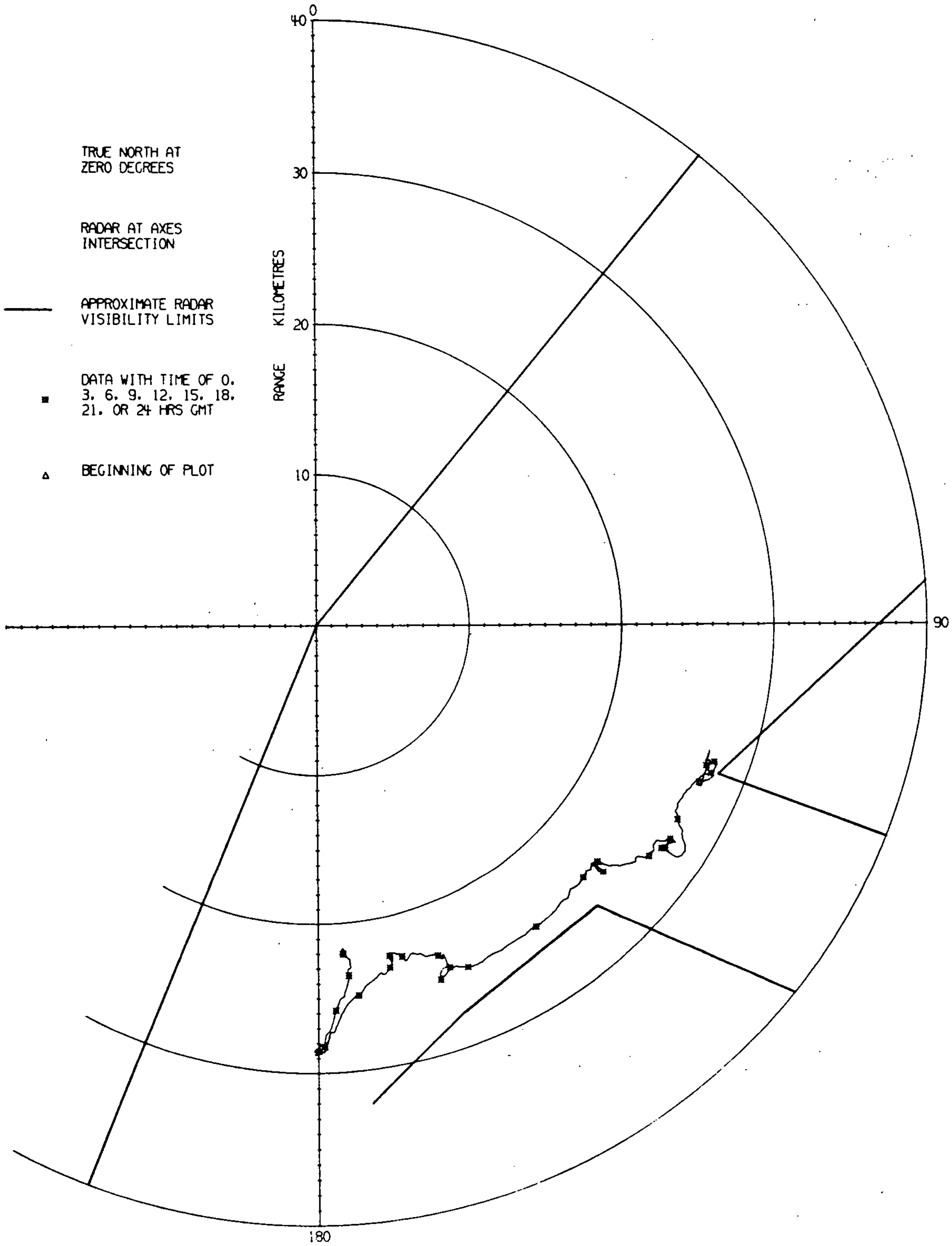

Fig. 16. *Station 7.2*
Start: 5 August 1449Z Finish: 8 August 1809Z

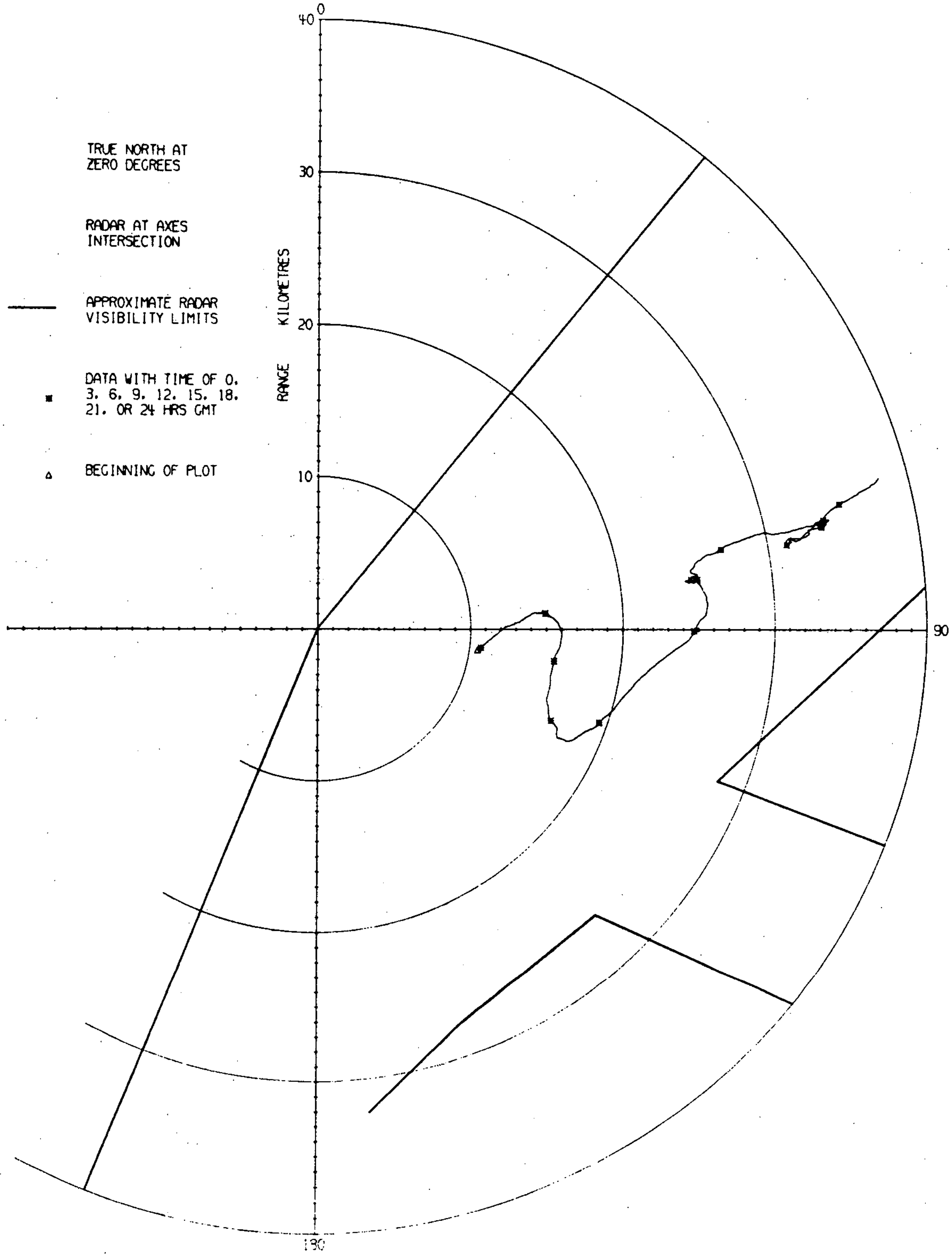

Fig. 17. *Station 6.5*
Start: 8 August 1744Z *Finish: 10 August 0710Z*

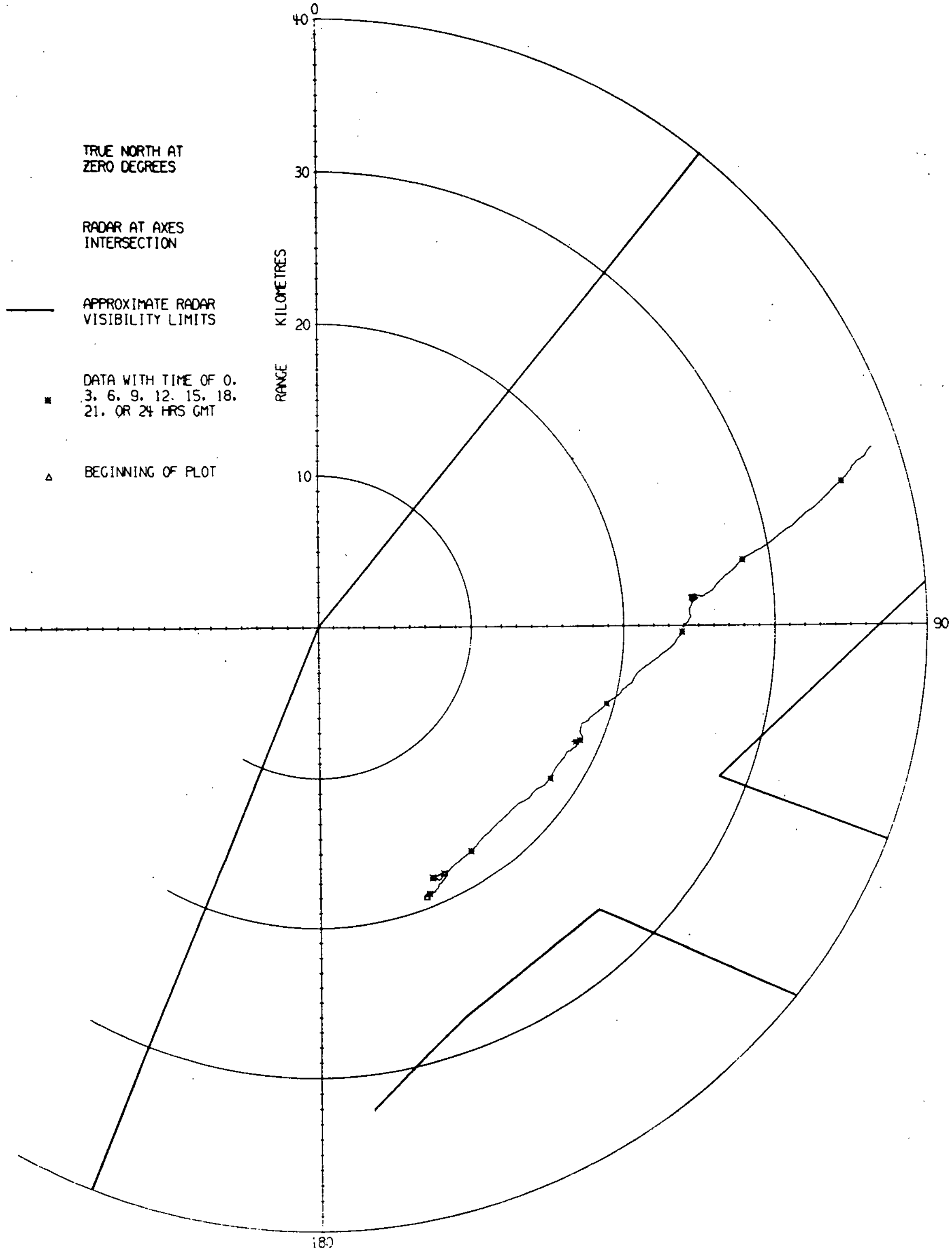

Fig. 18. *Station 8.3*
Start: 8 August 2015Z Finish: 10 August 1045Z

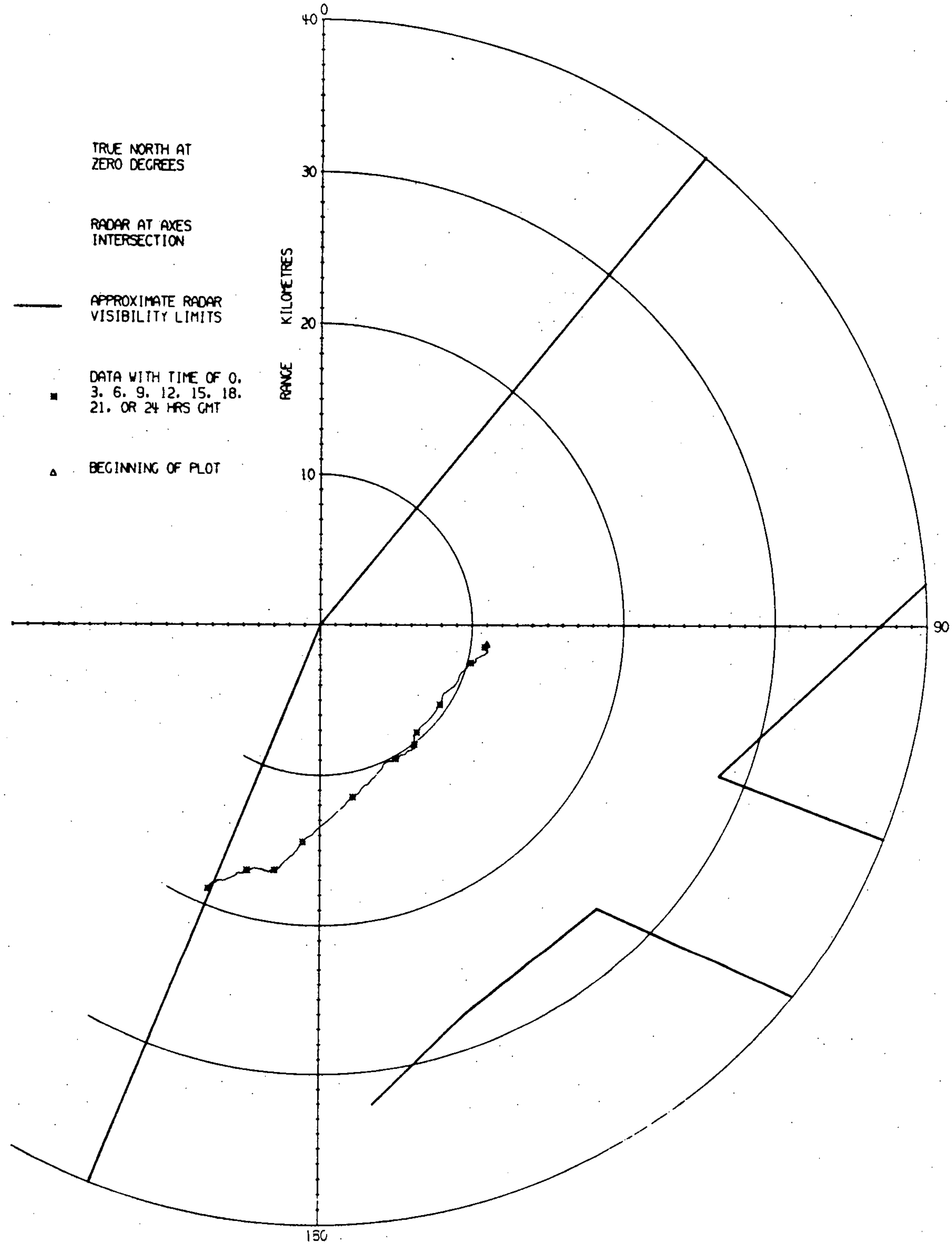

Fig. 19. *Station 7.3*
Start: 16 August 2246Z Finish: 18 August 0617Z

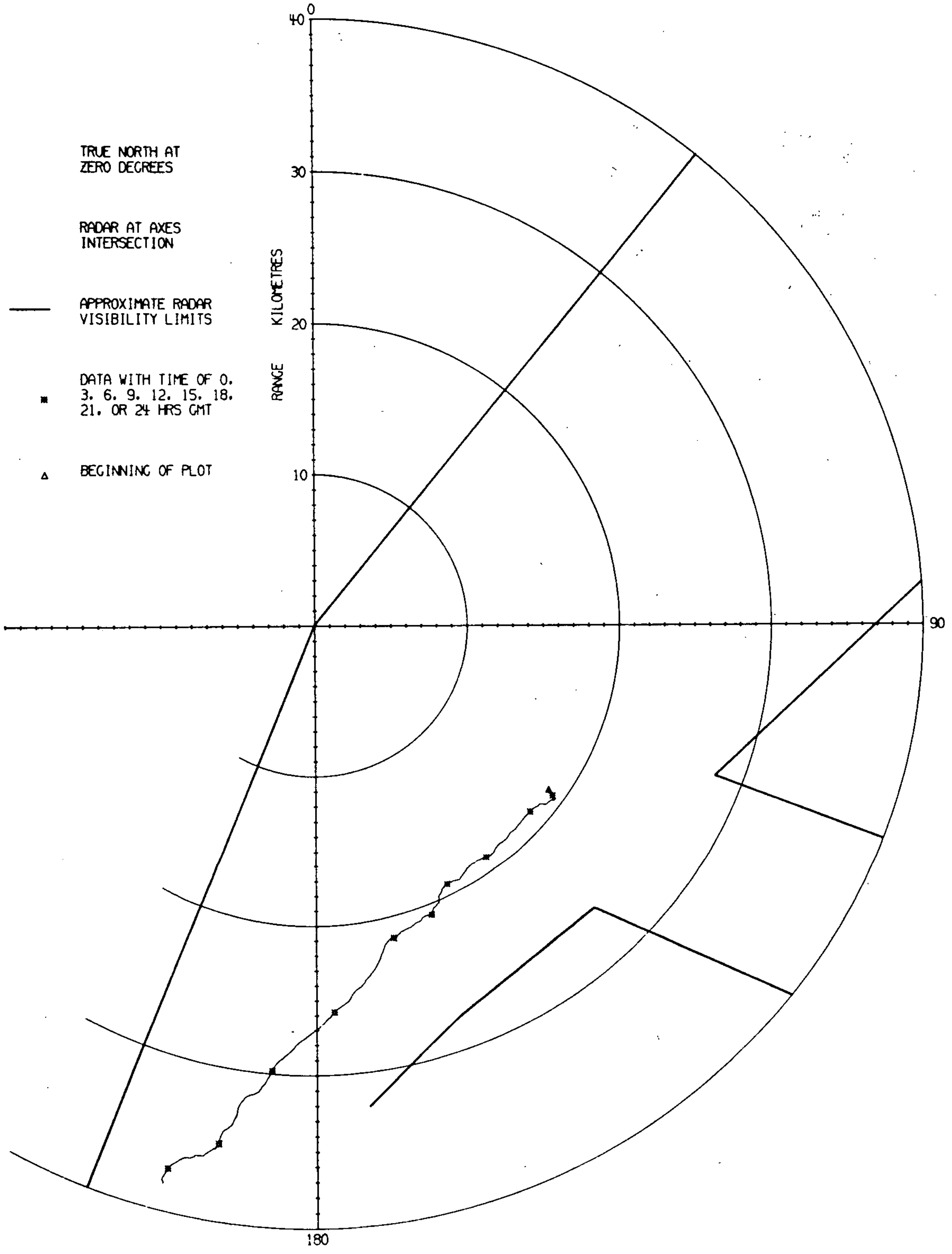

Fig. 20. *Station 6.6*
Start: 16 August 2327Z Finish: 18 August 0354Z

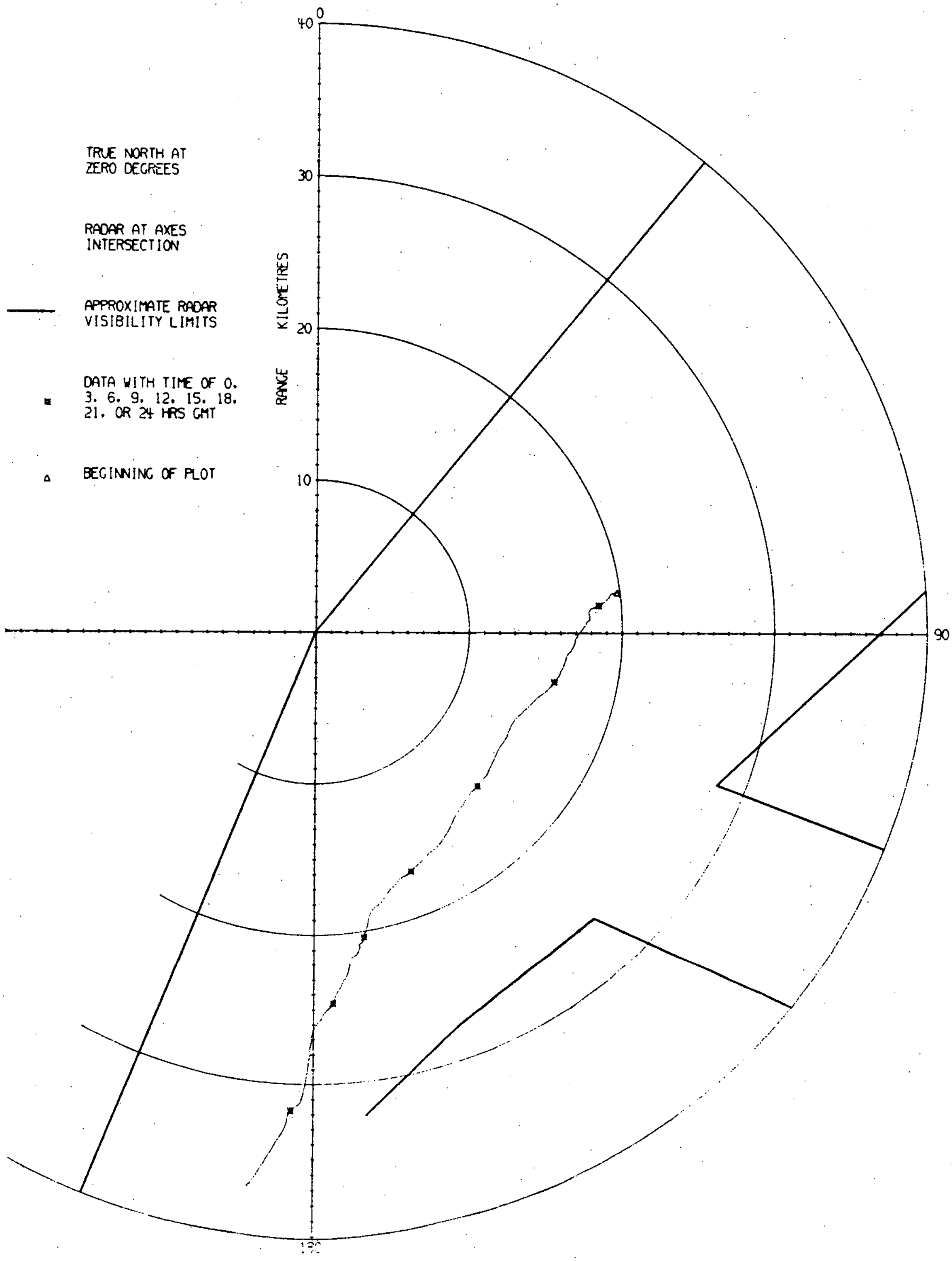

Fig. 21. Station 6.7
Start: 18 August 1340Z Finish: 19 August 1053Z

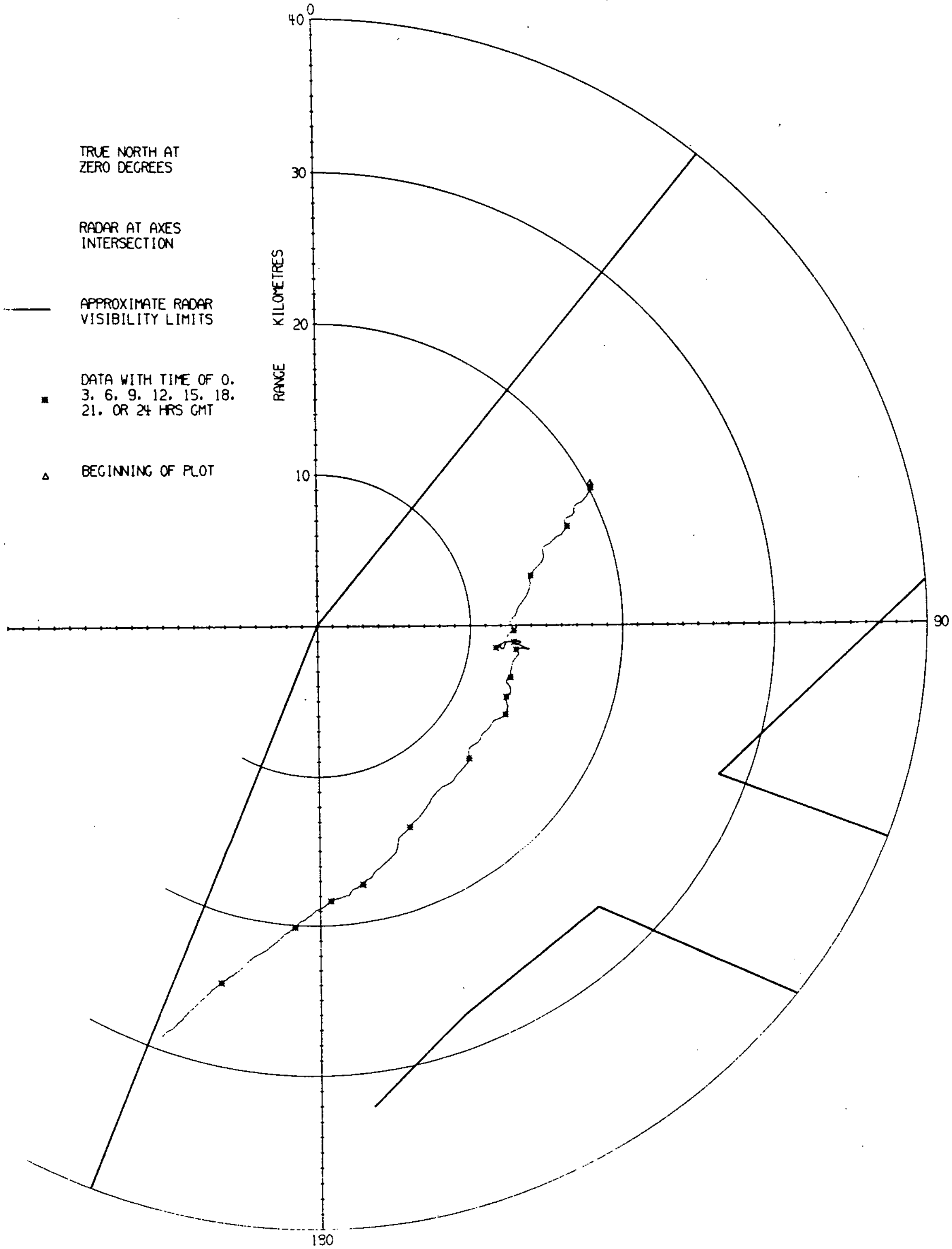

Fig. 22. *Station 6.8*
Start: 19 August 1427Z Finish: 21 August 1449Z

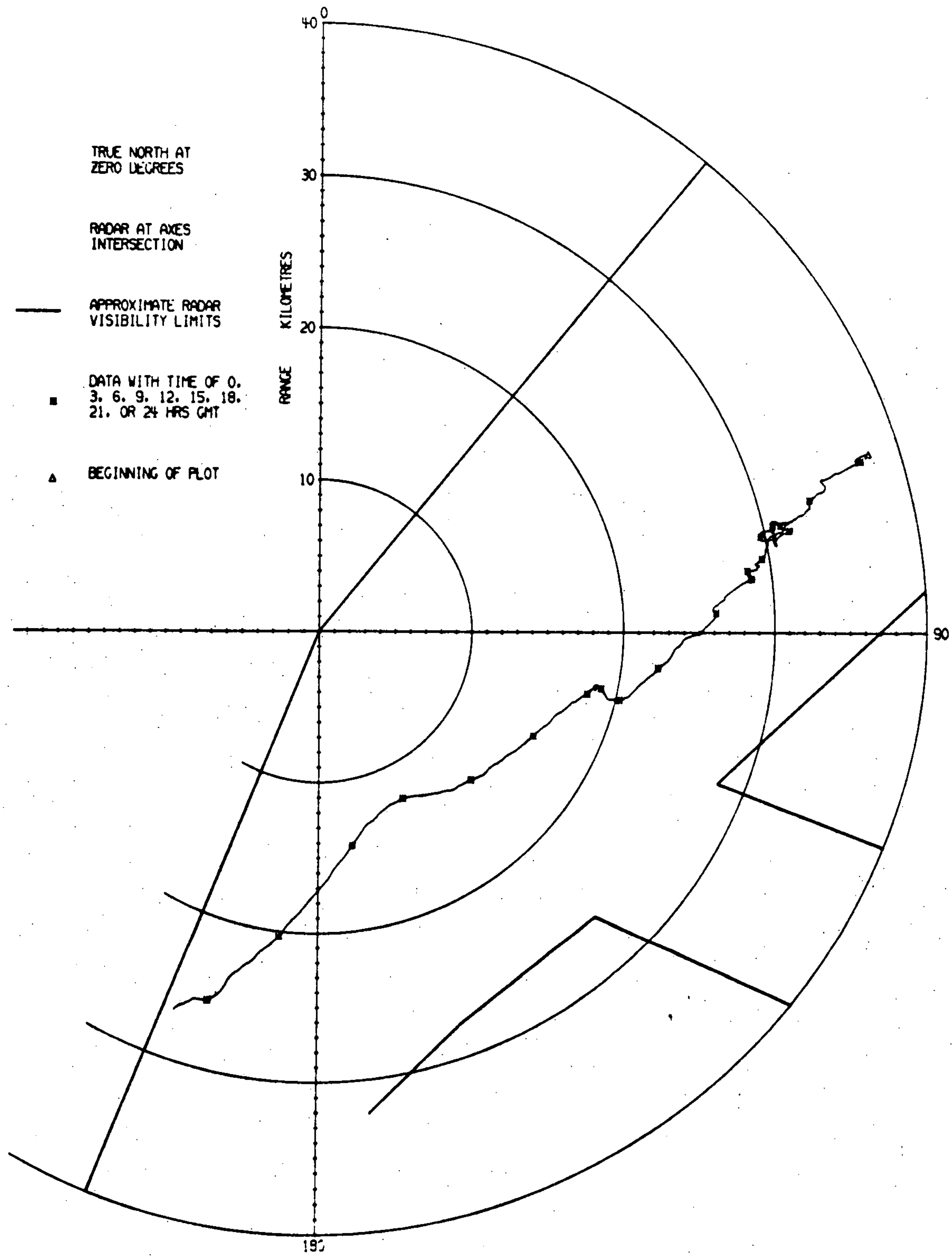

Fig. 23. Station 7.4
Start: 19 August 1645Z Finish: 22 August 0500Z

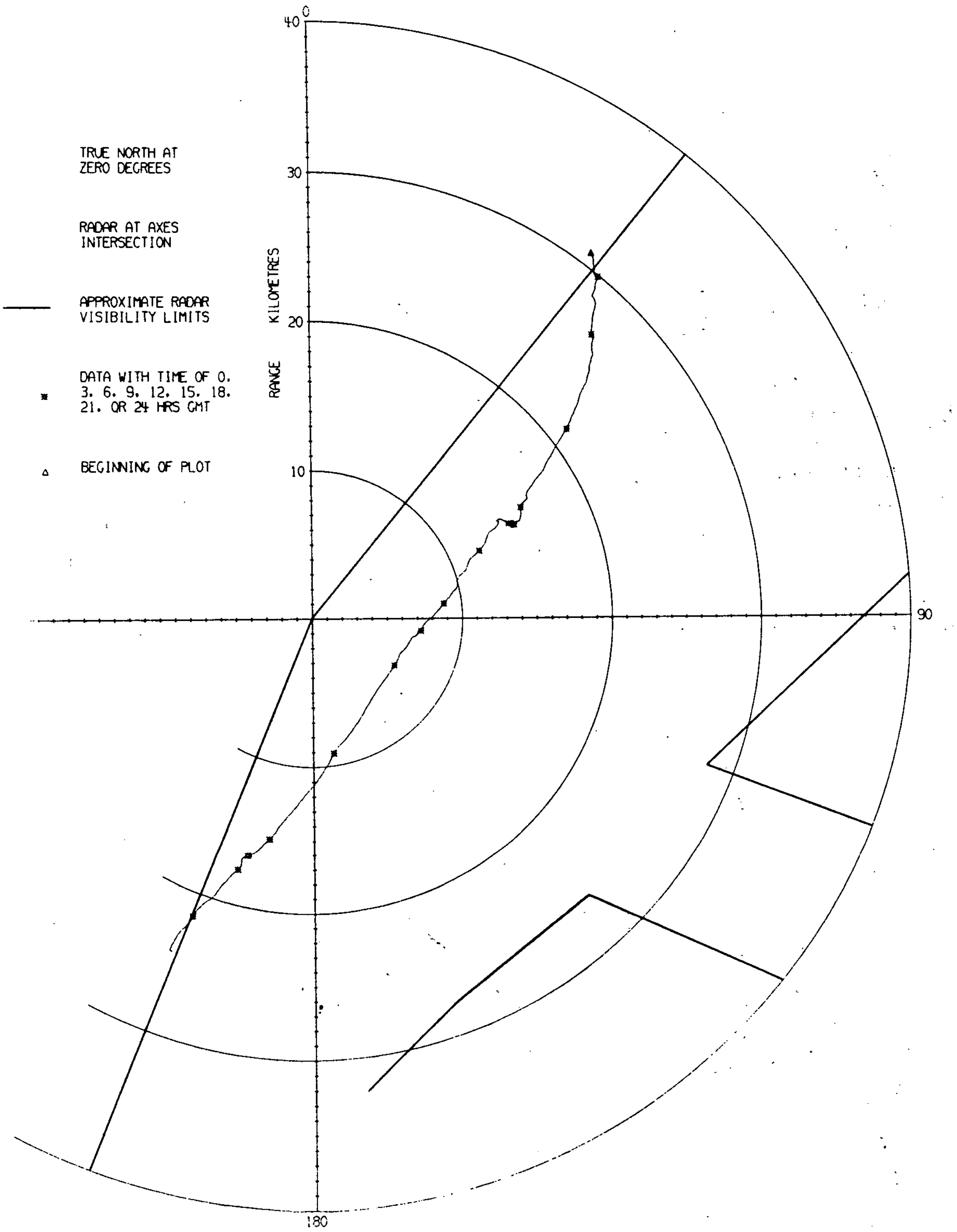

Fig. 24. Station 6.9
Start: 21 August 1623Z Finish: 23 August 1317Z

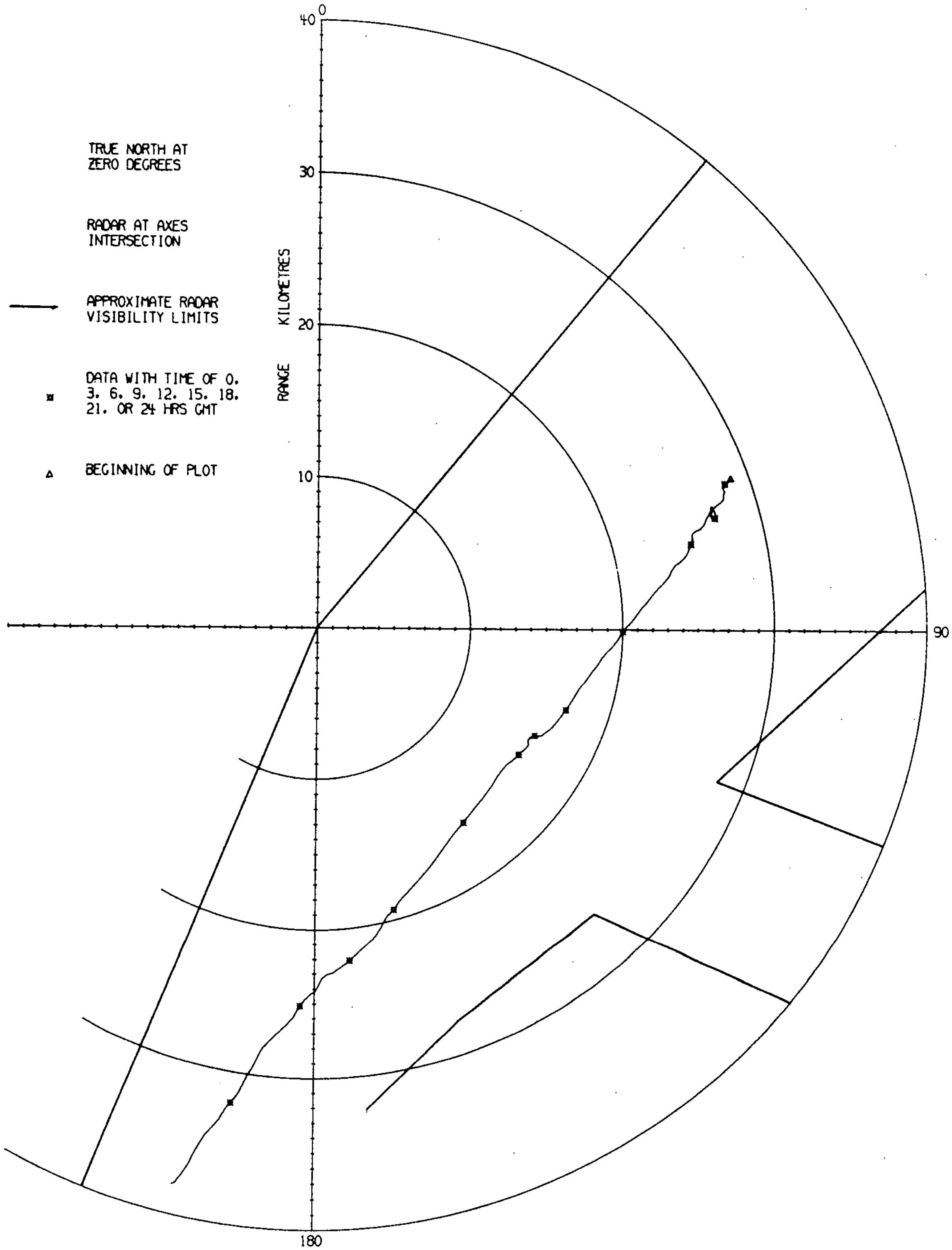

Fig. 25. Station 7.5
Start: 22 August 1436Z Finish: 24 August 0156Z

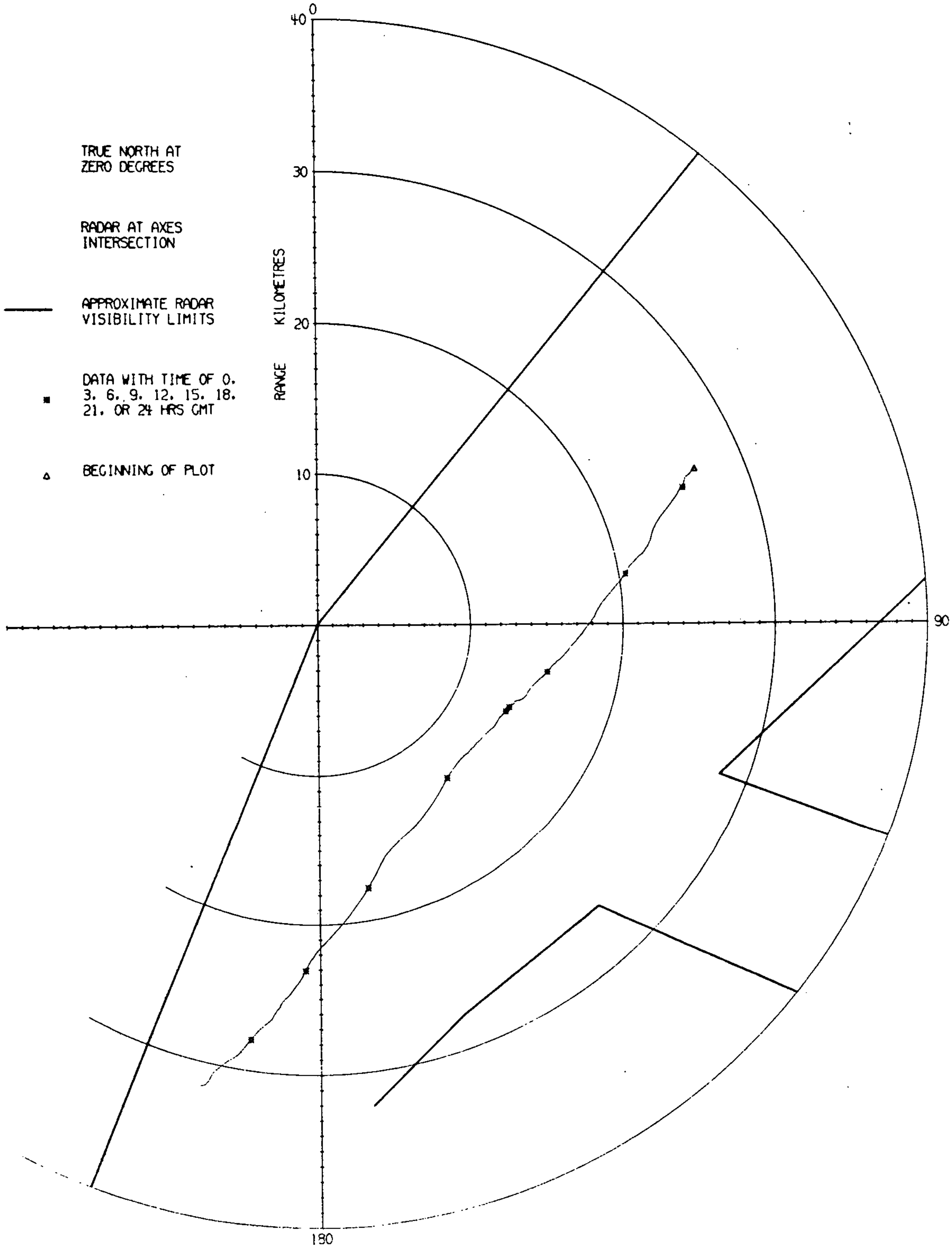

Fig. 26. *Station 6.10*
Start: 23 August 1958Z Finish: 24 August 2324Z

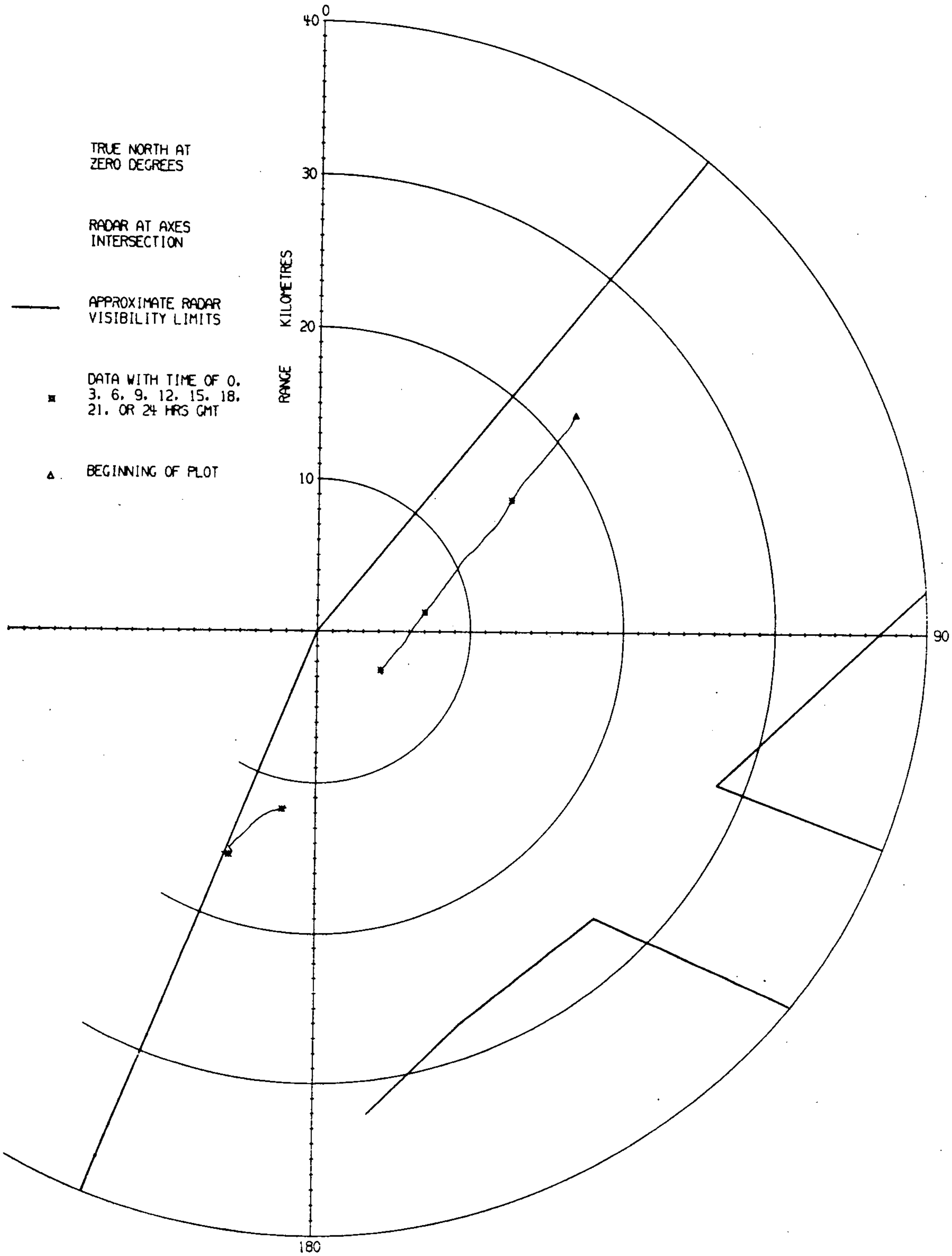

Fig. 27. *Station 7.6*
Start: *24 August 2106Z* *Finish:* *25 August 1857Z*

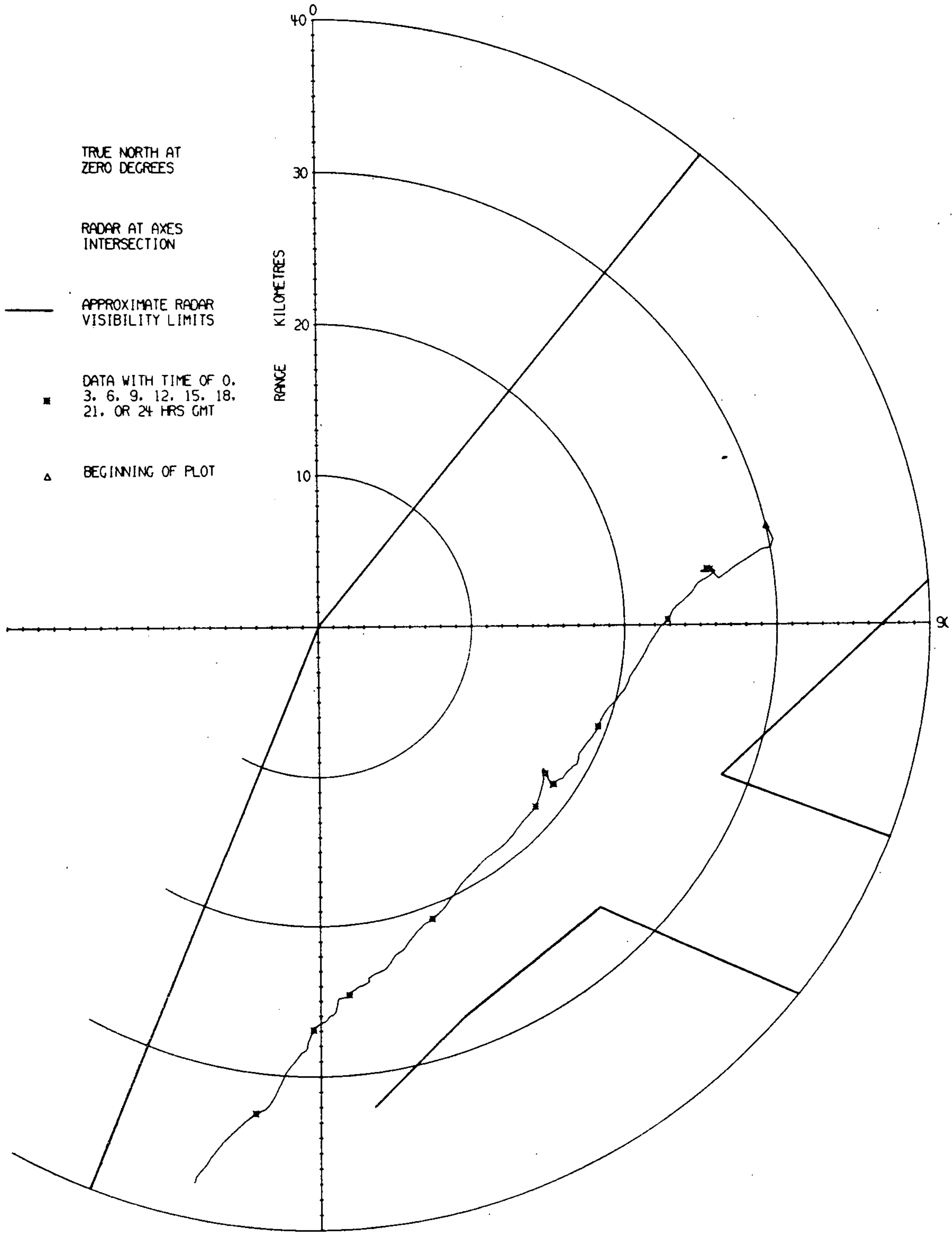

Fig. 28. Station 6.11
Start: 25 August 1538Z Finish: 27 August 0202Z

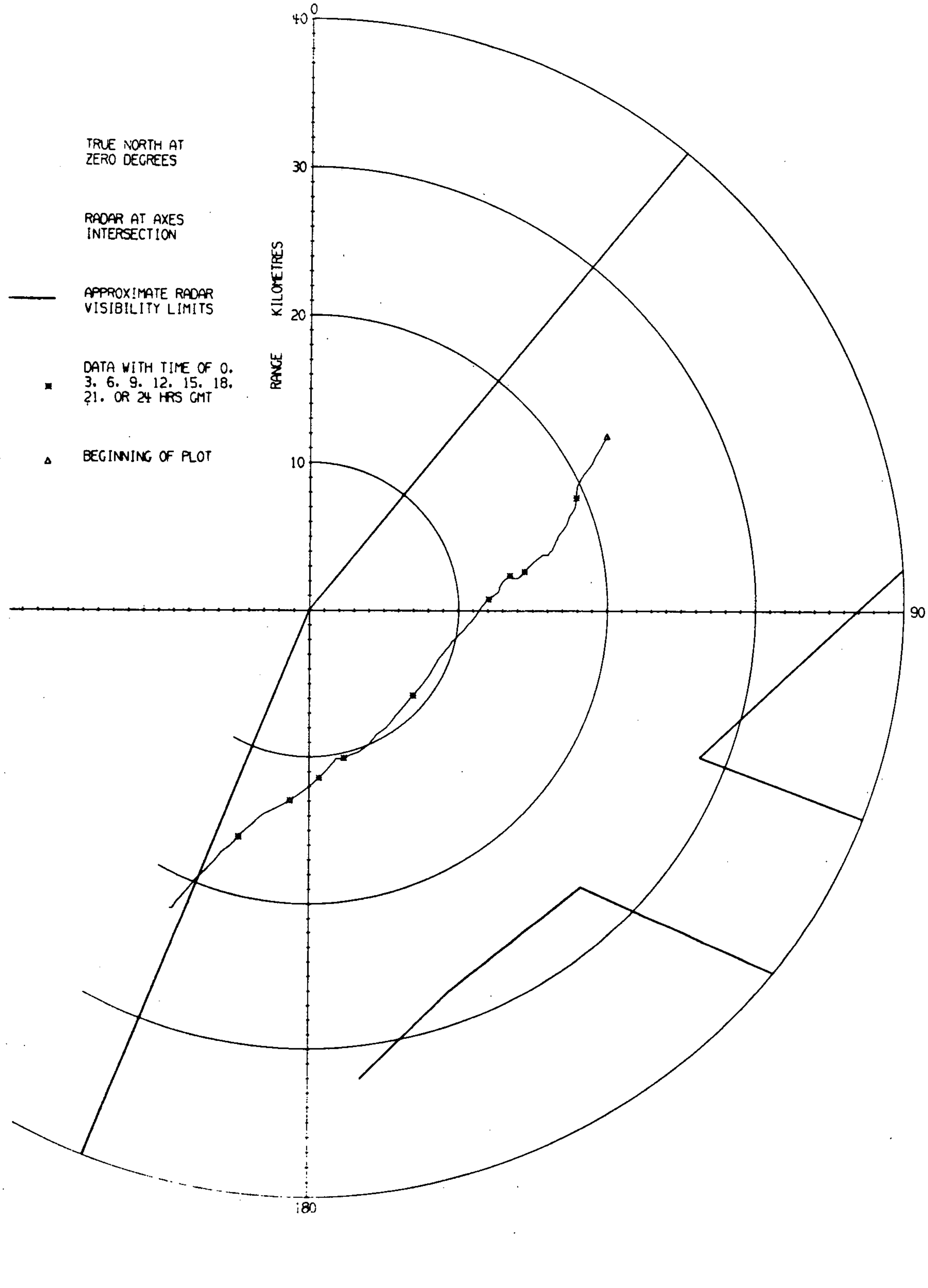

Fig. 29. Station 7.7
Start: 26 August 1307Z Finish: 27 August 1749Z

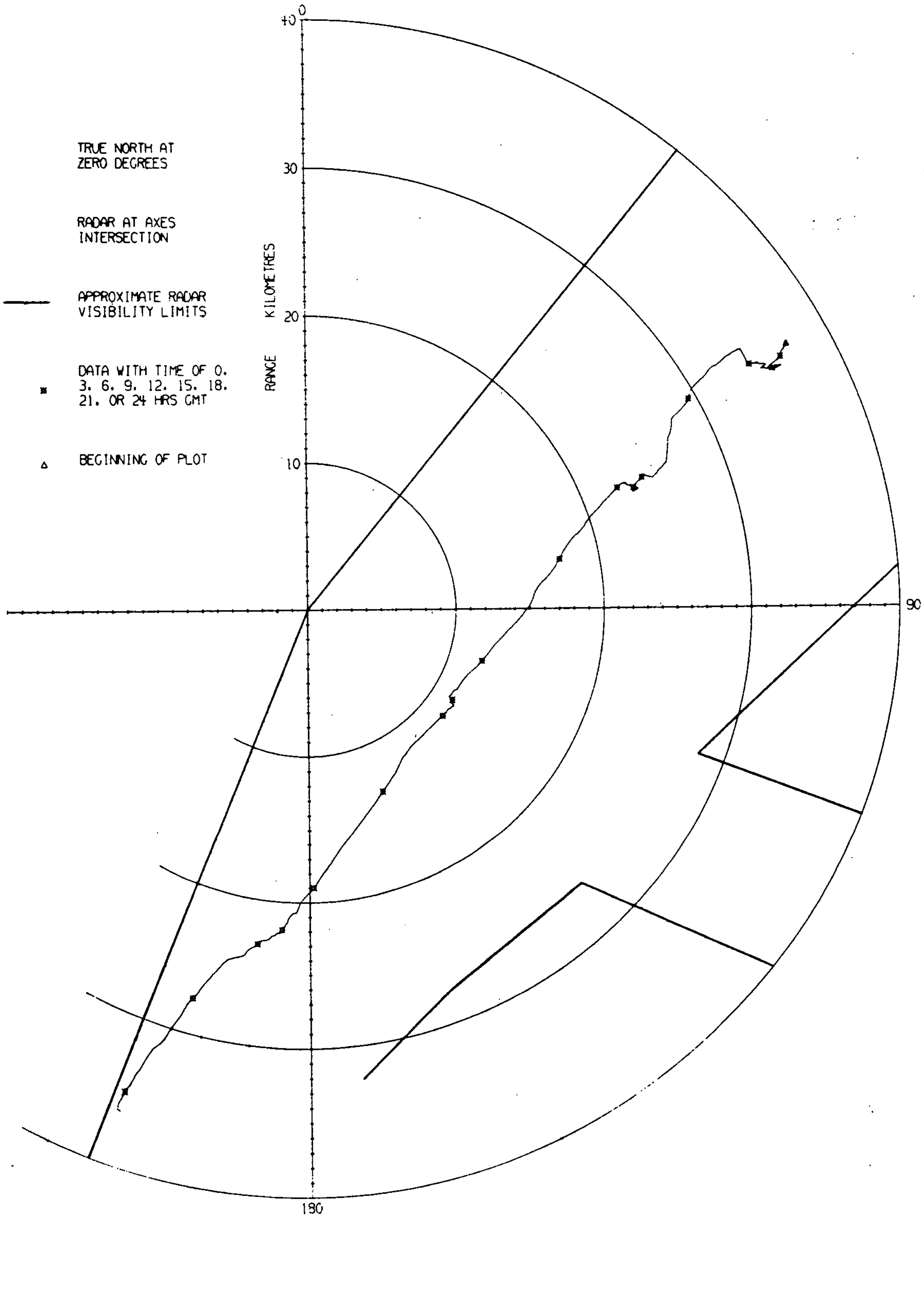

Fig. 30. *Station 6.12*
Start: 27 August 1725Z Finish: 29 August 1850Z

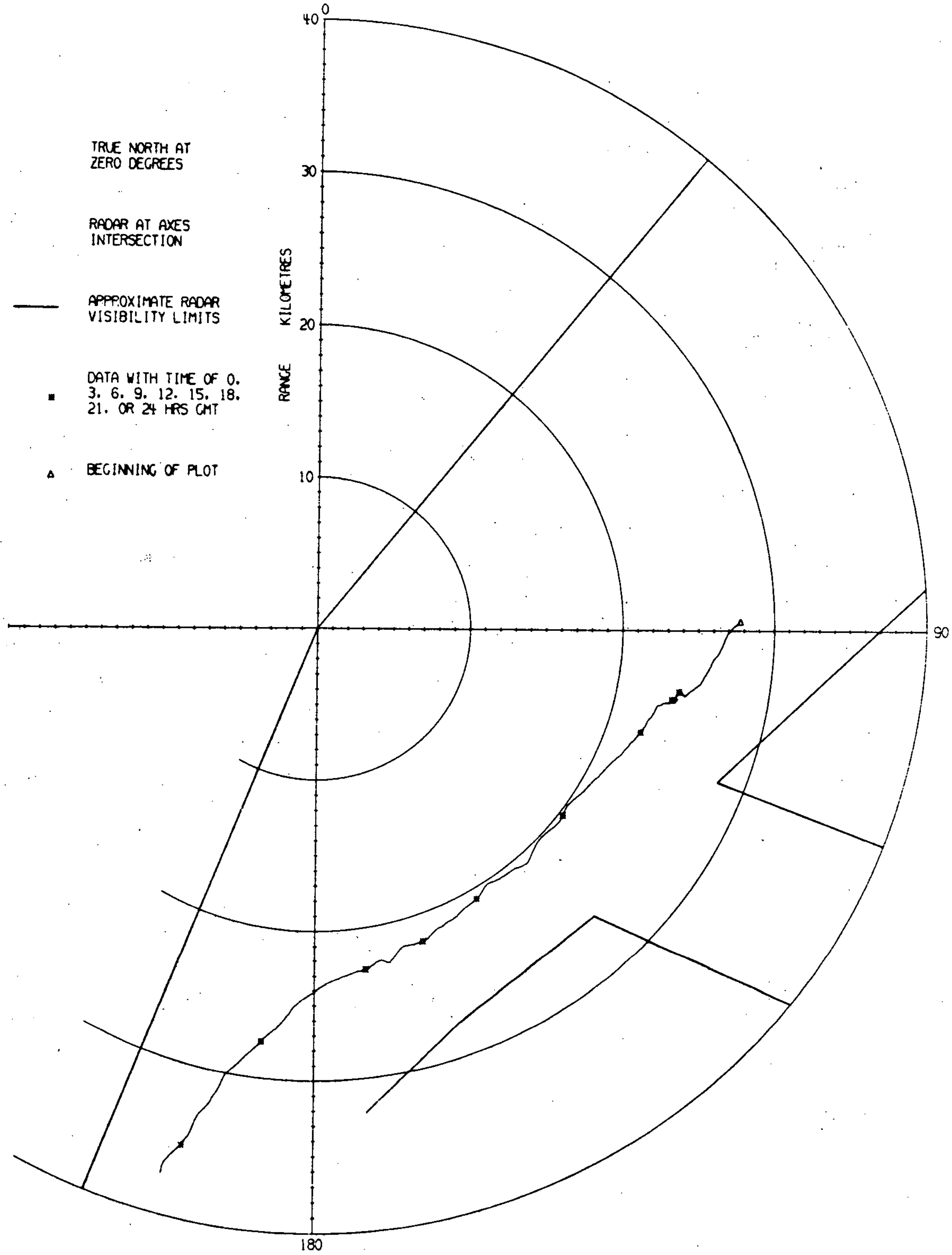

Fig. 31. *Station 7.8*
Start: *28 August 0323Z* *Finish:* *29 August 0652Z*

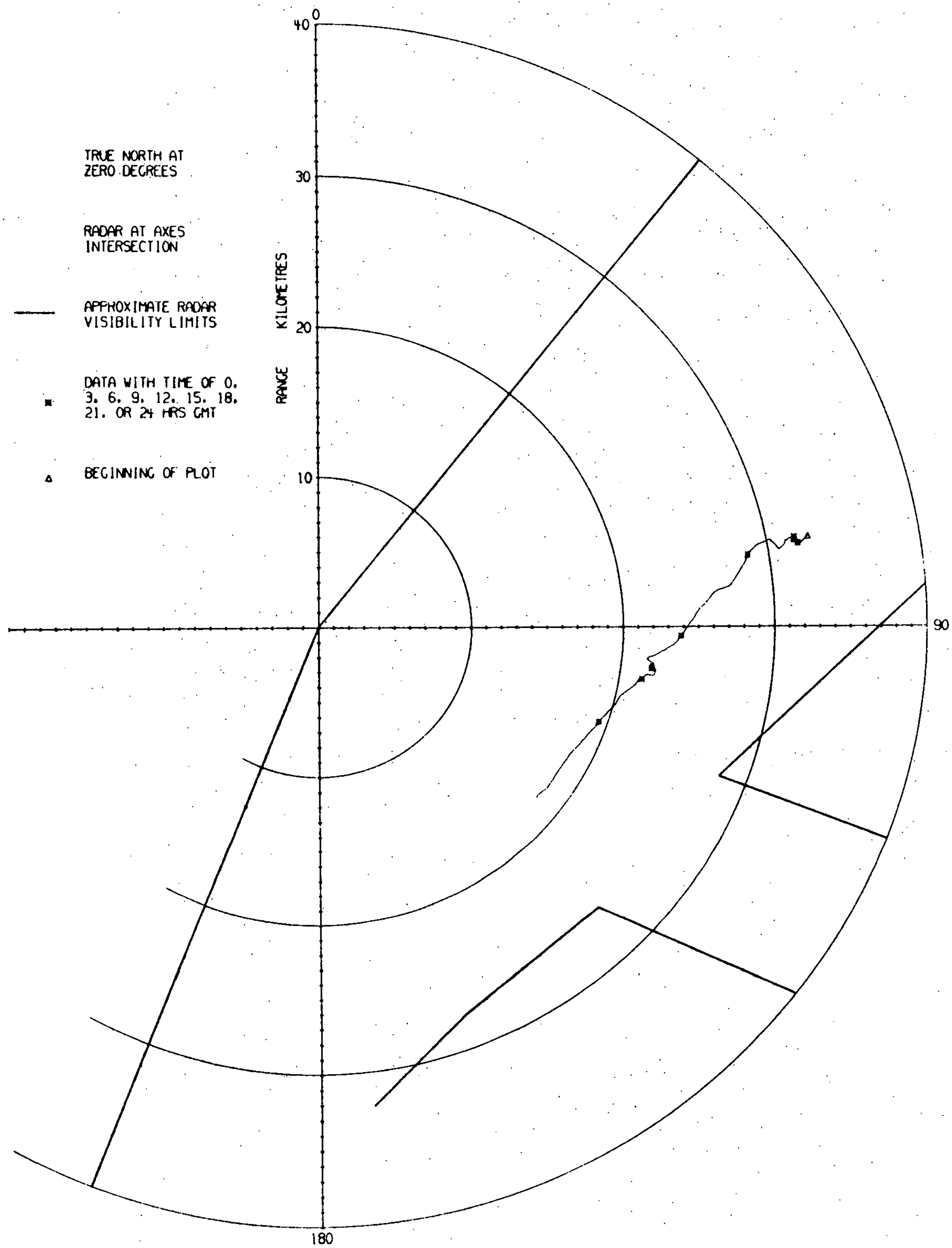

Fig. 32. Station 7.9
Start: 29 August 1957Z Finish: 30 August 1735Z

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13. ABSTRACT

ABSTRACT (UNCLASSIFIED)

This report describes a technique used for measuring ice drift in Robeson Channel, Ellesmere Island, using an X-band radar mounted on a cliff to track transponders placed on the ice. The transponder stations were equipped with wind recorders and, when possible, current meters. The PPI was read manually every hour and a film record made, one shot being taken per minute. The manual readings were fed into a computer and a plot generated in the field. The film record was later digitized and corrected plots made. These are included in the report, together with samples of the field plots.

Analysis of the data has not yet reached the reporting stage, but a few preliminary findings are given.

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KEY WORDS

Ice observations
Wind velocity
Robeson Channel
Tidal currents
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