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R.R.S. DISCOVERY

CRUISE 94

JASIN - 1978

12 July - 17 September 1978

Air-sea interaction: the structure of the upper ocean during JASIN 1978

CRUISE REPORT NO. 74

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SHIP'S OFFICERS

	Leg 1	Leg 2	Leg 3
Master	M.A. Harding	M.A. Harding	J.J. Moran
Chief Officer	J.D. Noden	T. Gray	T. Gray
Second Officer	R.I.P. Coutts	M. Putman	M. Putman
Third Officer	S. Jackson	S. Jackson	S. Jackson
Chief Engineer	D.R. Warlow	A.E. Coombs	D.R. Warlow
Second Engineer	N. Wilson-Deroze	C.P. Tottle	C.P. Tottle
Third Engineer	J. Richardson	J. O'Keefe	J. O'Keefe
Fourth Engineer	-	-	R. Whitton
Fifth Engineer	A. Greenhorn	A. Greenhorn	A.J. Davies
Fifth Engineer	A.J. Davies	A.J. Davies	R.M. Thomas
Electrical Engineer	P. Parker	P. Parker	B.J. Winchester
Radio Officer	R. Draper	R. Draper	R. Draper
Purser/Catering Officer	R.M. Cridland	R. Overton	R. Overton

INTRODUCTION AND OBJECTIVES

Discovery was one of fourteen ships and three aircraft participating in the Joint Air-Sea Interaction Experiment - JASIN 1978. The overall aims of the experiment and the full operational plans may be found in the Royal Society Publications "Air-Sea Interaction Project - Scientific Plans for 1977 and 1978" and " - Operational Plans for 1978" so will not be reported here.

Discovery's main tasks were

(a) to launch and track a drifting Spar (referred to as P2) carrying current meters from 14 to 50 m depth

(b) to track near surface floats measuring Lagrangian shear, dispersion and vertical velocities

(c) to conduct batfish surveys in the depth range 0 to 80 m

(d) to make directional wave measurements in conjunction with SEASAT passes and aircraft overflights.

All these tasks were accomplished with a substantial degree of success.

Discovery worked almost entirely within the Oceanographic Intensive Area (O.I.A.), that is within 60 km of 59°N, 12°30'W, known as the Fixed Intensive Array (FIA). This position lies in deep water in the North Rockall Trough. Track plots are shown in figs. 1 - 9. On many occasions work was done jointly with other ships, as the narrative will show.

JASIN 1978 was divided into three phases, labelled 0, 1 and 2, the initial phase being a testing period followed by two phases of intensive measurement. Cruise 94 was split into three legs, legs 1, 2, and 3 corresponding roughly with these phases.

The narrative that follows should be read in conjunction with the shipboard activity diagrams (fig. 16(a) - (j)).

NARRATIVE

Leg 1.

12 July - 17 July, 1978; days 193-198

Discovery left Barry at 1125 hrs. on 12 July (day 193) and steamed up the Irish Sea on her way to the JASIN area. Near 57°36'N, 10°44'W on the afternoon of 14 July (day 195) passage was interrupted for trials of a pitch-roll buoy, for the measurement of directional wave spectra and of a transponding acoustic float (remote interrogator) suspended at 10 m below a Dan buoy. Passage was resumed and after midnight near 58°30'N, 12°30'W the first two of a series of CTD stations were made; stations were spaced 30 km apart, occupied the full water depth and were accompanied by multisampler and thermometer observations. Their purpose was to assist us in the choice of a site to launch the Spar buoy P2. During 15 July (day 196) balancing trials were conducted on the Spar buoy in very calm weather and the Batfish was launched from the stern with the new Hiab crane. In the evening a 4 m acoustic float with canvas cross drogue was launched and after two hours recovered. CTD stations were continued overnight interspersed with the launch (and recovery) of a pitch-roll buoy to coincide with SEASAT altimeter measurements. On 16 July (day 197) final trials of the Spar buoy were conducted: the Spar was launched with acoustic transponder and back-up buoyancy but without current meters and recovered after ten hours in the water. Overnight the series of deep CTD stations was completed and *Discovery* returned to JASIN mooring H2 near 59°25'N, 12°31'W.

17 July - 20 July; days 198-201

After a brief trial of the Batfish, at 1200 hrs. on 17 July (198) the Spar buoy with six current meters was launched as IOS mooring 257: winds were less than 10 kts. In the afternoon trials were conducted on a plastic acoustically transponding float and during the evening the pitch-roll buoy was launched. Wire tests were made on new open head electromagnetic current meters (VAECM) and pressure telemetering (PT) transponding floats: these tests continued overnight and were interspersed with a series of shallow CTD lowerings to 200 m. On the morning of 18 July (day 199), after inspection of the Spar by a dinghy party, trials were started of the Batfish Control System, CTD system and new PDP 1134 computer logging system. These continued into the evening when a PT float was launched and shortly thereafter recovered. At 2100 hrs. (day 199) Discovery left the JASIN area and steamed to East Loch Roag on the Isle of Lewis to land a sick seaman.

20 July - 24 July; days 201 - 205

During our absence Challenger maintained watch on the drifting Spar buoy P2 Discovery relieving her at 0600 hrs. on 20 July (day 201). On the calmest morning of a prolonged period of undisturbed weather a PT float was launched, the Spar buoy P2 was recovered and a pitch-roll float launched in anticipation of aircraft photography of the sea surface. Because the PT float had remained at the surface, at 1300 a dinghy was launched and 30 gm weight added to the PT float causing it to sink. A short Batfish test followed before the pitch roll buoy was recovered - the aircraft did not show - and relaid for a SEASAT overpass. Both PT float and pitch-roll float were recovered by 2000 hrs and then the first float shear experiment was begun. A Dan buoy with light, radar reflector and remote interrogator at 10 m was launched along with floats measuring currents at 1, 2, 10 m depths: the wind was still very light. During the night the location of these floats was determined every half an hour and on the morning of 21 July (day 202) all gear was recovered near 59°31'N, 12°54'W before Discovery steamed back to H2 for further VAECM wire tests. By 2000 hrs. when a second float tracking experiment was begun, the wind was SE 25 kts. the strongest seen on this leg. At 0300 hrs. on 22 July (day 203) the pitch-roll buoy was launched for a SEASAT overpass and late in the morning, with the wind moderating all float gear was recovered.

We then began a 165 mile tow of Batfish in a dog leg from H2, first to a position near 58°20'N, 12°30'W at 2000 and thence to 57°13'N, 10°01'W by 0820 hrs. on 23 July (day 204). After recovery of the Batfish the passage to Glasgow was resumed and Discovery arrived at Yorkhill Quay at 1500 hrs. on 24 July (day 205).

Leg 2.

27 July - 1 Aug. 1978; days 208-213

Discovery left Glasgow at 1540 hrs.on 27 July (day 208) returning to the vicinity of the mooring H2 by 0700 hrs. on 29 July (day 210). In a light wind (S 10 kt) the Spar buoy with seven current meters was launched as IOS mooring 258: at 1030 hrs. the Dan buoy with radar reflector and 10 m remote interrogator was towed by dinghy to the Spar and tethered to the back up buoyancy. This rendered the mooring more visible and ensured that float tracking experiments remained close to the Spar, but wind drag was increased. An intended Batfish Survey was abandoned after a power supply failure and a float experiment was begun in mid-afternoon; floats at 1, 2, and 10 m were launched and tracked overnight. A pitch-roll float was launched at 0430 hrs. on 30 July (day 211) and recovered at 0730 hrs. in a wind S 12 kt. In the forenoon the floats were recovered and three 10 m drogued floats launched close together to measure dispersion. Overnight VAECM wire tests were made and on the morning of 31 July (day 212) the 10 m floats were recovered still very close together. In very light winds the Dan buoy and back up buoyancy tangled twice during the day and were straightened out by personnel launched in the dinghy. At mid-day we began a Batfish tow on a triangular course around the Spar buoy which was repeated at three hour intervals; the experiment was interrupted at 2100 hrs. to launch a pitch-roll buoy for a SEASAT overpass. Its recovery was delayed by an electrical fire in the Batfish winch until after the Batfish was brought in by hand at 1300 hrs. on 1 Aug. (day 213). In three days the Spar buoy had drifted 18 km to the NE of its launch position, moving further away from the FIA. the centre of the oceanographic programme. For this reason it was recovered by 1425 hrs. on 1 Aug. (day 213).

1 Aug. - 8 Aug.; days 213-220

Discovery steamed to a position 59°00'N, 12°45'W arriving there at 1930 hrs. and launched a 10 m drogued float; shortly thereafter a PT float was launched. During the night the pitch-roll buoy was launched and all gear was recovered by 1000 on 2 Aug. (day 214). Because the drift of the 10 m float was six miles west in about twelve hours this location was considered unsuitable for launching the Spar buoy. Accordingly Discovery proceeded to JASIN mooring B4 near 59°12'N, 12°30'W and at 1230 hrs. launched the Spar buoy with seven current meters as IOS mooring 259. A two-hour Batfish survey preceeded the launch of Cloverleaf buoy (to measure relative surface currents) and floats drogued at depths 25, 2 and 1 m. All were followed overnight and recovered by 1100 hrs. on 3 Aug. (day 215) with the aid of a dinghy. Near noon a much interrupted Batfish experiment commenced with Sawtooth and horizontal tows at 8 kt repeated every two hours around a square course. In this period were two pitch-roll buoy deployments (2100 hrs. day 215 and 0500 hrs. day 217) and transfer of personnel to Shackleton for CTD repairs (pm, day 216 and 217). Around 1500 hrs. on 5 Aug. (day 217) two days of float experiments began with the launch of floats at 1, 2, 10 and 25 m depth in 15 - 20 kt NNE winds: considerable windage was exhibited by an undrogued plastic float. The second experiment started at 1300 hrs. on 6 Aug. (day 218) in N 10 kt winds and involved the Cloverleaf buoy; between 1400 hrs. and 1800 hrs. Shackleton was stationed close to P2 making repeated CTD dips and current shear measurements. Later in the evening of this same day, the pitch roll float was launched for a SEASAT overpass and next morning Shackleton returned to P2 continuing shear and CTD work (0700 hrs. - 1200 hrs.) In five days the Spar had drifted 55 km west from its launch position; consequently, P2 was recovered at 1300 hrs. on 7 Aug. (day 219) and Discovery steamed east towing the Batfish to a position near 59°08'N, 11°53'W where at 2200 hrs. a 10 m float was launched. Overnight a Batfish survey was made around the fixed intensive array. Recovery of the 10 m float showed a south current so Discovery steamed two hours to the West.

8 Aug. - 16 Aug.; days 220-228

Near 59°09'N, 12°18'W at 1130 hrs. on 8 Aug. (day 220) the Spar buoy with seven current meters was launched as IOS mooring 260. Prior to this deployment the pitch-roll buoy was launched to coincide with aircraft photography of the sea surface; after a change of plan the buoy was recovered and then relaid at 1600 hrs. for the aircraft experiment. In the meantime a 25 m drogued float was laid near P2 and Batfish tows around a two hour square course began: this was the start of an experiment which lasted three and a half days. At first Sawtooth and constant depth tows were alternated but by 0400 on 10 Aug. (day 222) these were replaced by slow 15 minute ascents and rapid descents of the Batfish. During the experiment the 25 m depth float was recovered (2200, day 221), as it proved a hazard to navigation, and the pitch-roll buoy deployed (SEASAT overpass) at the same time. Shackleton was on station near P2 on the 8th (1945-2400 hrs.), 10th (0900-1315 hrs.) and 11th (0900-1415 hrs.) making CTD and shear observations. On 10 and 11 Aug. (days 222-3) the wind was SE 20-25 kt but just prior to Batfish recovery at 0600 on 12 Aug. (day 224) it decreased sharply to SSW 10 kt for the launch of four floats drogued at 1, 3, 10 and 25 m. Shackleton returned and made shear measurements between 1200 and 1700 hrs. The Cloverleaf buoy was launched and recovered twice during the day, the second time when all the floats were recovered. Overnight a PT float was tracked, its equilibrium depth was near 20 m; but a second launched later descended to near 250 m. On the next day, 13 Aug. (day 225), the Cloverleaf buoy was again launched, this time in an ESE wind 20 kt and in conjunction with 1 and 25 m drogued floats. A pair of PT floats was launched and tracked overnight, equilibrium depths 30 and 80 m, and all floats recovered by 0730. The Spar buoy was recovered near 59°33'N, 13°03'W by 1000 hrs. on 14 Aug. (day 226) and Discovery steamed for Glasgow arriving at Yorkhill Quay at 1030 hrs. on 16 Aug. (day 228).

Leg 3.

20 Aug. - 27 Aug. 1978; days 232-239

After a delay of 12 hours while a stove-in porthole was sealed, Discovery left Yorkhill Quay, Glasgow at 2100 hrs. on 20 Aug. (day 232). After initial problems with the subsidiary fish beneath the batfish, a batfish section was run on passage to John Murray's position starting at 1100 hrs. on 22 Aug. (day 234). A radar marker was set for John Murray at 59°45.6'N, 12°29.5'W, intercomparisons were made and the batfish section continued south past H2 to B4 where a 10 m drogued float was launched. Because of a fault in the batfish strain cable, only sea surface temperature was logged on a run to mooring P1 and back before the Spar P2 was launched (IOS mooring 261) at 1400 hrs. on 23 Aug. (day 235) near B4 in 20 kt winds. The spar drifted S and had to be towed clear of W3 at 1600 hrs. on 24 Aug. (day 236). Thereafter the wind decreased and it drifted W until recovered on 27 Aug (day 239). During this period (23-27 Aug.) there were two overnight shear float experiments (1, 3, 10, 25 m) and two 'buoycross' experiments (i.e. launches of the pitch/roll buoy during near-noon overflights by the U.K. Met. Research Flight C130 aircraft). After wire tests on 25 Aug. (day 237) a batfish survey round the FIA was done (fig. 6) while Shackleton remained close to P2. PT float tests, CTD yoyos within a few cables of P2 and constant level batfish tows were made on 26 Aug. (day 238) until P2 (mooring 261) was recovered at 0930 hrs. on 27 Aug. (day 239).

27 Aug. - 1 Sept 1978; days 239-244

In order to choose the best site for the first multiship experiment, three 25 m floats were then launched South of the FIA. Two PT floats were added on 28 Aug. (day 240) and all floats except one were recovered that evening. After a short batfish test run, Discovery, Meteor and Planet made a joint CTD yoyo series from 0100 to 0600 on 29 Aug. (day 241).

The Spar was then launched (IOS mooring 262) south east of the FIA at the start of the first multi-ship experiment (survey ships Discovery, Atlantis II, Endeavor; stationary ships Planet, Tydeman, Shackleton Poesidon) and the last PT float recovered. Eleven batfish circuits (fig. 7) of a 4 mile square box round P2 and outside all other ships ended at 1040 hrs. on 30 Aug. (day 242). The wind which had been around 10 kts. for the previous 6 days, increased to 20 kts. at about this time. After a buoy cross experiment, a survey round and south of the FIA (fig. 8) was run until 1140 on 31 Aug. (day 243). During this period Planet and Poseidon remained close to P2. After a buoy cross, a shear float experiment was done until the morning of 1 Sept. (day 244) as the wind decreased to 10-15 kts. During this time a float and drogue became entangled with the surface temperature fish. It was freed after being towed for about five minutes but contact with it was lost some two hours later, and it was presumed sunk. Two PT floats were tracked on 1 Sept. (day 244) in conjunction with CTDs and a buoy cross, and all gear including the spar was recovered by 1600 hrs.

1 Sept. - 8 Sept. 1978; days 244-251

In preparation for the second multi-ship experiment, Discovery then steamed to H2, and after a single float run and batfish test circuits of H2 overnight, P2 was relaunched (IOS mooring 263) early on 2 Sept. (day 245). There followed four days of batfish circuits, frequently interrupted. During the second multi-ship experiment (Discovery, Atlantis II, Endeavor, roving; Planet, Poseidon, Meteor, Shackleton, fixed) Discovery proceeded in line behind Endeavor and in front of Atlantis II for ten square circuits of H2 (fig. 9) and continued after their departure until Atlantis II hauled H2 late on 3 Sept. (day 246). All further circuits until 1700 on 6 Sept. (day 249) 27 in all, were round P2.

On 4 Sept. (day 247) the remote interrogator attached to P2 was found to be flooded, and was replaced. The wind, which had been near calm during and since the second multi-ship experiment, was increasing during this operation, so the decision was taken to continue batfishing. By midnight (0000 hrs.

on 5 Sept., day 248) the wind was over 30 kts and remained 20-30 kts for the following 48 hours. By mid-morning on 5 Sept., a pitch/roll buoy launched in the heavy seas overturned after only a few minutes. When the batfish was being relaunched it swung against the ship and was out of action for eleven hours while the wings were repaired. CTD runs at constant depths were made in this period, but the loss of data at such an important phase in the development of the mixing layer was disappointing. From 6 to 8 Sept. (days 249 to 251) shear float tracking and PT floats were alternated, and three hourly XBTs were launched in a joint experiment with the Akademik Vernadsky. One boat party was required in this period, to replace a flag that had been knocked off a PT float during launch. Winds fluctuated, but frequently reached 20 kts or more.

8 Sept. - 12 Sept.; days 251-255

After a pitch/roll buoy deployment on 8 Sept. (day 251) for an SAR pass, the spar was recovered and a batfish survey run past Akademik Vernadsky, Planet, Tydeman and Challenger participating in the third multiship experiment. A PT float was tracked overnight with XBTs and later yoyo CTDs until the spar could be relaunched at 1600 on 9 Sept. (day 252) as IOS Mooring 264. Batfish circuits were again begun, and this time continued uninterrupted for nearly 3 days, 21 circuits in all, until 1400 on 12 Sept. (day 255). Because of heavy swell, the circuits took the form of elongated triangles with one side stern to swell and the other two 15° on either side of the swell direction. Winds fluctuated considerably during the batfish circuits, but were frequently over 20 kts and reached 30 kts by noon on 12 Sept. (day 255).

12 Sept. - 17 Sept.; days 255-260

Shear floats deployed on the afternoon of 12 Sept. (day 255) were recovered with difficulty the following morning (13 Sept.; day 256) in 25-30 kt winds with a heavy swell. A single PT float was then launched, but by mid-afternoon the Master considered the constant cross-swell manoeuvering to follow the float too dangerous, and it had to be abandoned. Manoeuvres were limited to occasional turns to return to the spar. Early on 14 Sept. (day 257) XBTs had also to be discontinued, and after 0830 the vessel was hove to in 30-40 kt winds. By mid-afternoon a lull permitted the recovery of the spar to be attempted, and it was recovered without damage on the second attempt, after tether lines had caught round the bow the first time. After searching for the PT float until 2000 hrs, course was set for South Shields where the ship docked at 0900 on 17 Sept. (day 260).

NOTES ON EQUIPMENT AND OBSERVATIONS

1. Drifting Spar Buoy P2 (R.T. Pollard, I. Waddington, Miss M. Saunders)
Leg 1.

The spar buoy consists of three ten inch diameter aluminium cylinders, each three metres long, surmounted by a two metre long 4.5 inch diameter surface piercing spar. The total buoyancy of the system is a little under 600 lbs. The bottom cylinder can be surrounded by a 26" diameter Fabion fabric sleeve, held out from the cylinder by four rods held by damping plates. The natural period of the spar with the sleeve trapping seawater to provide added mass is about 25 seconds, without the cover it is 17 seconds.

Handling and buoyancy trials were carried out on 15 and 16th July (days 196/197) with lucas weights and no instrumentation. On the first setting, after adjusting the buoyancy and removing the sleeve the spar was allowed to drift away from the ship on a long tether, and watched for three hours to check for any leaks or absorption of water. On the next day, the cover was replaced, and the spar set free from the ship, tethered on a 25 m line to a pitch/roll float with light. Fifteen pairs of trawl floats were attached to the tether to give emergency buoyancy. It was recovered after drifting for ten hours.

These trials established a pattern for future deployments. Handling lines are required top and bottom of the spar to prevent it swinging as it is lifted into the air. Once the surface piercing spar is close to the crane jib the spar cannot swing and is easily handled. As it is lowered into the water, the strain is taken on a long tether round the capstan and the crane hook released. The line is paid out to test the buoyancy and then pulled in again to hold the spar close to the ship's side while the tether, floats and pitch/roll buoy, and danbuoy (if attached) are lifted outboard. On recovery, the spar is easily pulled up on the capstan until the crane hook can be inserted in a short strap at the base of the surface piercing spar. Deployment, and recovery once grappled, take only 30 to 40 minutes with full instrumentation.

There was one instrumented deployment (257) of three days duration during leg 1 (Table 1). Six VACMs were used in two sets of three joined by 2m rods to prevent differential rotation. The system was initially 28 lbs. heavier than calculated. The discrepancy has not been accounted for. Weights were removed and two trawl floats added to adjust the buoyancy. On recovery, eight pairs of trawl floats had been lost, and wear was apparent on the five ton polypropylene line where the trawl floats had been and where two lines had been shackled together. Wear below the spar was minimal.

A second setting planned for Leg. 1 was cancelled because of time lost to land a sick seaman and because of inclement weather. Open head VAECMs were wire tested instead.

Leg 2.

There were three deployments (258, 259, 260) on this leg. The trawl floats were replaced by five blue and white Norwegian floats which rode well in the water and caused no wear. In addition, a dan buoy with a remote interrogator beneath it was tethered to the pitch/roll float. Radar as well as visual bearings could thus be made on the drifting system and the range checked by either the remote interrogator or the transponder (channel 17) under the spar.

On each setting, one VACM was a few metres under the spar, with two strings each consisting of VACM-rod-VAECM-rod-VACM beneath.

Leg 3.

There were four deployments (261-264) on leg 3, each with 5 VACMs and 3 VAECMs. One VACM and one VAECM were as close to the spar as possible at 14 and 16 m, the rest in two strings of three as in Leg. 2.

The pitch/roll float and dan buoy with remote interrogator were attached as for Leg. 2. Launch and recovery were not difficult even in heavy swell, though on one recovery the line between the spar and pitch roll float went under the ship at the first attempt in difficult conditions. On one occasion, the spar had to be grappled and towed clear of the FIA, but no harm appears to have been done. Aften ten days of strong wind and swell, tether lines were significantly frayed, but could probably have lasted as long again.

Navigation of spar

To track the spar as well as possible, regular fixing of its position was attempted. During float tracking, radar range and bearing, supplemented by acoustic range were obtained half hourly, apart from gaps usually while floats were being set/recovered. During batfishing the ship was moving too fast for radar bearing and ship's position to be taken closely enough in time, unless the radar and Loran were read simultaneously by two people. Instead two or more acoustic ranges on the spar were obtained whenever the ship passedclose by it, usually every two or three hours. Finally, on occasions, Discovery left the spar for longer periods when another ship was prepared to remain in its vicinity.

Summary of spar drift

257 - Spar set 5 miles N of H2, drifted W 18 km in 3 days. Tended by Challenger for part of period when Discovery was on passage to/from East Loch Roag 2200/199-0700/201.

258 - set close to H2, drifted NE 18 km in 3 days

259 - set one mile S of B4, drifted W 57 km in 5 days

260 - set six miles E and one mile S of B4, drifted to NW 62 km in 6 days.

261 - set a few miles SW of B4, drifted rapidly S towards the FIA, and had to be towed W from 1600 - 1700/236. It then drifted W. Fixed by Shackleton 0000 - 1100/238 during batfish survey of FIA.

262 - set SE of FIA at start of first multi-ship experiment. Drifted 26 km SE in 3 days. Radar fixes by Planet, Shackleton, Poseidon until 1200/243.

263 - set 7 miles NW of H2 at start of second multi-ship experiment. Drifted S then W overall 34 km in 6 days.

264 - set near B4 position (though mooring already hauled). Blown in various directions mainly S then N ending up close to launch position.

R.T. Pollard

2. Vector averaging electromagnetic current meters.

(C. Clayson, K. Birch)

Leg 1.

Due to unsuitable weather, the VAECMs were not used on the 10 m spar during the first leg of the cruise. Instead wire tests were carried out to the south of mooring H2 with each meter on the hydrographic winch for ½ hour periods at 10, 20 and 30m depths. Loran-C navigation was used to obtain true currents but was not sufficiently accurate for good results over this time scale. The data obtained was, however, a useful check on the operation of the three new instruments.

Leg 2.

All five instruments were used on the 2nd leg of the cruise. Two VAECMs with horizontal and vertical open head sensors were used on each of the three deployments of the drifting spar buoy P2, totalling approximately 16 days. Two VAECMs with discus heads and a further VAECM with horizontal and vertical open heads were used on the Cloverleaf buoy, in various combinations, during its five deployments.

As would be anticipated for the first production instruments, a few problems - due to manufacturing defects - were encountered. Of the 6 records obtained from the spar VAECMS, two had faulty vertical currents due to a faulty circuit board. One of the discus head VAECMs suffered from zero shifts until a faulty regulator was discovered. When two meters were deployed on the Cloverleaf, using a common compass, problems were again encountered and have yet to be resolved fully: fortunately, one of the pair always gave good results.

Much valuable operating experience was gained, enabling the establishment of a routine procedure for checking out and servicing the meters between deployments.

C.H. Clayson

Leg 3.

Three VAECMs with open head sensors for both horizontal and vertical scale measurements were used for a total of 21 days recording on the spar buoy P2 during the 3rd leg of the cruise. Good records were obtained on all but one occasion when battery failure occured during the deployment.

K. Birch

3. Float tracking (P.M. Saunders, N. Millard)

Three kinds of experiments were planned using acoustically tracked floats; Measurement of (i) shear in near surface currents, (ii) dispersion at fixed depth and (iii) vertical motion in the mixed layer. At a later date to these were added intercomparison experiments with currents measured from the drifting Spar buoy P2 and the Cloverleaf buoy.

Although we were prepared to determine the location of a float using bottom transponders, as in the JASIN '77 experiment, throughout cruise 94 we adopted a method which employed a remote interrogator hung below a drifting surface buoy. This method avoided frequent launching and recovery of the bottom transponders which would have been necessary in order to remain close to the drifting spar buoy P2. In brief, a fix was obtained as follows - a series of 5.1 kHz transmissions from the ship established the two way transmission time from the ship to the float; then a series of 7.1 kHz transmissions from the ship established the two way transmission time from the ship to the remote interrogator. The remote interrogator responding at 5.1 kHz was also heard by the float whose response was, in turn, detected at the ship: thus was measured the round trip travel time, ship-remote interrogator-float-ship. Since both travel times from ship to float and remote interrogator were known, the travel time from remote interrogator to the float could be deduced. The remote interrogator was hung at 10 m below a dan buoy which carried a radar reflector at a height of about 3 m: hence the bearing of the remote interrogator was measured and finally the float position determined relative to the ship. Each float had a distinctive reply frequency allowing up to sixteen to be tracked simultaneously.

Any experiment was limited in its duration primarily by the time it took a float to drift out of the combined range of both ship and remote interrogator. When several floats were fixed simultaneously the restriction was more severe than this since it was also necessary to maintain good geometry for accurate fixes. Ranges for surface floats rarely exceeded 3km and during mid-afternoon on the first two legs of the cruise the range was nearer 1.5km only. Dispersion or shear experiments thus lasted only 12-18 hours before the floats had to be gathered up.

In order to make a current measurement at a particular depth we decided to make the transponding float (slightly) buoyant and attach a drogue to it at the required depth. Drogues were in the form of a canvas cross, 1.5m on a side, stretched over a plastic frame and held spread using thin cord from corner to corner. In water each drogue weighed approximately one kilogram - very close to the payload of a 4m Swallow float. Because of this limitation and because of the size and drag of the 4m floats, we had constructed six plastic floats with a payload of 3.5kg and an overall length of less than 2 m. These plastic floats were easier to launch, had smaller drag and allowed weight to be added to the drogue to improve depth-keeping: they were invariably employed in making shear and inter-comparison measurements. Drogued floats were launched with the ship steaming very slowly upwind: the superstructure provided sufficient shelter on the poop to assemble and launch the drogued floats over the stern even in strong winds.

Three of the 4 m long Swallow floats were fitted with 250 db pressure transducers and modified to give a double reply when interrogated, the delay between responses measuring the pressure at the instrument (sensitivity ·015 sec./db). In addition, a polythene drag plate, 6 mm thick and 0·9 m on a side, was clamped about one third of the way from the top of the tube. We planned to make the floats neutrally buoyant in the mixed layer and measure weak vertical motions there. This was known to be a difficult task since for equilibrium depths the total float weight changes only about 1 gm for 7 db pressure change, 5 gm for 1°C temperature change and 3.5 gm for 0.1‰ salinity change. We became convinced that in calm seas the very small excess weight of the float when launched was easily overcome by the buoyancy of trapped air, so we adopted the practice of adding an excess 100-250 gm of load via a slowly dissolving confectionery (polo).

In all there were about 130 transponder launches (Table 2); we failed to recover two - once when the ship backed into a plastic float when (not) maintaining Station and once when due to bad weather we steamed away from a float and could not re-establish contact with it 24 hours later. Throughout the two month cruise transponders failed to act properly on three occasions and only very minor problems were encountered with listening and recording equipment.

P. M. Saunders

4. Batfish and Sea Surface Temperature (R.T. Pollard, J. Smithers, G.Griffiths, V.A. Lawford, D.S. Collins, T.J.P. Gwilliam)

Batfish and sea surface temperature surveys and time series formed a substantial part of the cruise program. Excluding time spent on deployment, recovery, instrument failures, etc., useful sampling spanned 17.5 days (420 hours) for the batfish, longer for SST, over 10^8 words of data in all.

Apart from instrumental problems during Leg 1 and at the start of Leg 2, the SST fish, towed from a forward boom, was deployed throughout the cruise, and sampled whenever the ship was under way. These data were used to map surface features and select areas for batfish and drifting Spar deployments. They form a valuable adjunct to the CTD data from the batfish. A subsidiary fish under the batfish sampled temperature for some of the time, but because of noise problems coupled with handling problems in rough weather, it was left off towards the end of the cruise.

Three main types of tow pattern were used:-

(1) survey patterns around the FIA and sections on passage, yoyos to 70 - 80 m every 3 minutes (100 hours)

(2) 2 to 3 hour repeated runs around square or triangular circuits with

yoyos usually to 40 - 55 m every 1.5-2 minutes (76 hours)

(3) repeated runs as in (2), but with either horizontal tows or very slow profiling (1 m in 100 - 250 m) to not deeper than 50 m (245 hours) These runs are summarized in Table 3.

Throughout all sampling, the data, supplemented by Loran C navigational information, were logged to a PDP 11/34 and live time series profile plots and track plots were obtained. The PDP 11/34 system, described elsewhere in this report, worked excellently and must be considered an integral part of the batfish system.

Runs were frequently interrupted for other operations, such as pitch roll buoy deployment, remote interrogator recovery. In retrospect, such breaks are undesirable in time series runs and should be avoided if possible in future. The batfish was out of action for twelve hours on one such occasion when the wings were damaged during relaunch, losing a particularly interesting period of mixed layer development.

R.T. Pollard

Batfish Operation

Leg 1.

The Batfish was launched several times during the early part of the cruise to prove the engineering modifications made.

The towing of the vehicle is now satisfactory. On a long - 200 m - unfaired cable, no significant yaw was measured. Depths approaching half cable length were attained. However, the special water bottles failed to operate and will require some modification before being satisfactory. A damaged towing cable caused some delay during the early part of the cruise.

The new crane fitted to the aft deck of Discovery proved to increase the safety of both launch and recovery operations, though practise was required in the operation of crane and winch in unison.

The cruise ended with a Batfish tow of some 20 hours, during which the oscillation was maintained between approximately 5 m and 80 m with 4 to 5 minute periods.

Leg 2.

The Batfish was used regularly throughout this Leg of the cruise, totalling over 140 hours in the water and covering a track some 1800 Km long. The program culminated in a non-stop run of 52 hours. The runs were interrupted several times by the launching and recovery of various floats, but it was found that the Batfish could be lifted clear of the water and allowed to hang on the crane well clear of the ship, rather than recovering it inboard. (In retrospect, this is not advised, as it probably contributed to termination problems later experienced - Pollard).
A mini fish, hung 2½ m below the Batfish and carrying temperature sensors was used. However, due to the problems of screening the connecting cable and interfacing into the CTD these sensors were not often available. Four general patterns of tow were used.

(1) Fast yoyo, 3 m - 50 m every minute.

(2) Medium yoyo 3 m - 80 m every 4 minutes.

(3) Slow yoyo 10 m - 30 m, 14 minutes up - 1 minute down.

(4) Horizontal runs close to the surface and close to the thermocline.

Unfortunately it was not possible to get the water bottles operational during this Leg. Early on in the cruise the cable winch electrical system caught fire causing some damage to cabling and to the diesel starter solenoid; temporary repairs were made.

V.A. Lawford

Leg 3.

During Leg 3 the Batfish/CTD system with and without subsidiary fish, was deployed for six surveys. The total number of runs was 114, 257 hours in all.

Performance of the system was very good on the whole, with routine servicing keeping failure to a minimum.

The first service was performed after runs 084-096. The hydraulic oil was clear of water, but a small hole through half the thickness of the ram diaphragm was found. This item was replaced. At the end of run 087 the electrical cores of the towing cable were damaged inside of the towing block, thus necessitating replacement.

Runs 099-123 were completed without problems. Service showed oil free of water but containing rubber particles. These had been scuffed off the inside of the diaphragm. The inside of the hydraulics was cleaned and a new diaphragm fitted.

Runs 124-162 were again successful, but during deployment for run 163 the line to the subsidiary fish caught over the lower rear batfish wing. While attempting to clear this the batfish was swung against the stern rail fracturing the port wing and bending the rudder. The rudder was straightened and the wing repaired with a fibreglass bandage.

Runs 169-178 were successful, but service showed a burst diaphragm with approximately 50% water in the hydraulic units. This was thoroughly cleared and a new diaphragm fitted. The subsidiary fish was removed for these runs as it had failed and due to heavy seas handling over the stern was made easier without it. New glass filled PTFE bushes were fitted to the ram fork end and phosphor bronze bushes to the wing shaft and bridle.

Runs 181-183 and 185-205 were completed without trouble.

J. Smithers

Sea Surface Temperature Sensor

This instrument was developed for the 1978 JASIN exercise to measure fast changing sea surface temperatures (time constant 100 m sec.)

The "fish" containing the temperature sensor had its initial test during Leg 1 while en route to the JASIN area. Unfortunately, it was struck by flotsam and the towing cable had to be repaired. On further deployments the fish behaved very well for speeds up to 8.5 knots but in heavy seas tended to drift away from the ship. This drift was quickly corrected when the sea came off and had no tendency to oscillate. At greater speeds the fish drifted away from the ship until it eventually broke surface then swung right in to the ship's side, occasionally hitting it.

The sensor probe, with the thermistor element mounted on the tip was found to be difficult to handle, due to its delicate nature, and breakages occurred. In repairing the probes the thermistor element was set into a groove for protection and this proved easier to handle as well as not detracting from the original time constant.

The sensor deck unit functioned satisfactorily throughout Leg 1 providing data to the CAMAC system. The fish was deployed for much of the time while in the JASIN area on all legs.

T.J.P. Gwilliam

5. Lowered CTD and HP 2100 (P.M. Saunders, J. Smithers)

Installation of the double width platform for the electric winch, both for lowered CTD work and instrument wire tests, was greeted with pleasure and was found as helpful as had long been anticipated.

After the first deep CTD station (Table 4) had been successfully made it was found impossible to acquire CTD data on the HP 2100 computer for the succeeding eight stations even though the computer functioned satisfactorily in every other respect. The difficulty arose on the interface card and has yet to be resolved. Eventually a method was found to bypass the problem and seven of these stations were logged in the replay mode. Station 9830 was unfortunately lost when the backup analogue tape was overwritten. The deep CTD instrument and multisampler was transferred to the SHACKLETON at the end of Leg 1.

At the beginning of Leg 3 a new (Brown) CTD unit was brought on board; its arrival coincided with a tape unit failure which was repaired at very short notice by the Glasgow area HP engineer. The new CTD instrument had a large conductivity cell, a temperature sensor with fast response thermistor and a temperature compensated pressure transducer; on yoyo casts, for which it was exclusively used, the up and down salinity values were found systematically different (order .03$^{o}/_{oo}$).

At the end of Leg 1 the capstan motor on the Sea Data cassette tape recorder was replaced: all the current meter tapes recovered from the Spar buoy could then be decoded and listed and plotted measurements obtained via the HP 2100. The new location of the computer in the forward Plot, where it was securely bolted to the floor, allowed the operators plenty of space but also exposed them on occasions to rather violent pitching motion.

P.M. Saunders

6. XBT (P.M. Saunders, I. Waddington)

On Leg 3 of the cruise sixty 450 m depth XBTs were launched (Table 5) principally in support of float tracking experiments. A new hand launcher was employed and found to be satisfactory.

P.M. Saunders

7. Pitch-Roll Buoy (D.J. Webb, C.H. Clayson, K.G. Birch)

Leg 1.

The pitch-roll buoy was deployed on six occasions. There were two successful intercomparisons with the SEASAT wave height estimates from its altimeter. One of these intercomparisons was during a period of calm seas and the other during a period of heavy seas.

It was planned that for the SEASAT intercomparisons and the C130 photographic runs a minimum of two hours data would be obtained.

The failures on the 17th and 20th July (Table 6) were due to water seeping in through the light housing. On the 20th July this caused extensive damage to the printed circuit boards. A small crack in a weld in the bottom of the electronics compartment was also found.

On the 20th July the C130 was reported to be on a general reconnaissance but did not reach *Discovery*. The SEASAT pass of the 17th July was missed because *Discovery* had to land a sick seaman.

Attempts were made to read the data on the PDP 11/04 and transfer it to magnetic tape. These failed because personnel were required to get the PDP 11/34 systems working, the supplied magnetic tape unit did not work and the 11/04 developed hardware faults. Although requested, time was not made available on the 11/34. Data input to the 1800 was not recommended because the 1800 CAMAC system contains faults. In addition it was stated that a lot of programming would be required. (D.J.W)

The buoy was fitted with an acoustic transponder to assist in recovery: the transponder was suspended below the centre of the buoy canister on a 10 m rope and did not affect the surface following performance of the buoy significantly although the buoyancy margin was reduced. Apart from the above mentioned sea water damage, the hardware worked satisfactorily although some problems were experienced initially with the gyro caging mechanism lock. (C.H.C)

Leg 2.

The pitch-roll buoy was deployed on six occasions to cover SEASAT passes and once while the C130 was taking sea surface photographs.

There were no major problems with the pitch-roll buoy. It leaked slightly once and the batteries lost power after about 2 hours so that the giro tended to topple over. (D.J.W.)

Buoy number 1 was used on the occasions described above. No further trouble was experienced now that all leakage problems had been rectified. The radio beacon was only marginally powerful for location of the buoy during aircraft crosses so that it was decided to use dye markers for future flights. (C.H.C.)

Leg 3.

(1) SEASAT

There were no SEASAT altimeter passes through the JASIN area, and when his own pitch-roll buoy developed a compass fault, Bob Stewart on Atlantis asked us to cover 5 synthetic aperture radar passes with our pitch-roll buoy. Because of other commitments we were only able to cover two of these passes and on one of these the buoy overturned after obtaining only 2½ minutes of data.

(2) Directional spectra of sea waves from photographs

During Leg 3 the aircraft took sea surface photographs on five occasions; low cloud prevented photographs being taken from the intended 4-8000 ft and instead they had to be taken from 1-2000 ft. This probably does not matter too much as the wavelengths observed during JASIN were shorter than had been expected.

Working with the aircraft was difficult. On one occasion we thought they would arrive at 1300 hrs.- they arrived at 1500 hrs. On other occasions they only gave half an hours warning of their arrival. Some of this was due to a professional terseness in their communications. This had an affect on the other experiments being carried out by the ship.

Data Processing

The PDP 11/04 was used to check that the pitch-roll buoy was giving reasonable data. The magnetic tape units and interface still did not work properly - so serious data processing can take place only after the raw data tapes have been re-read at I.O.S. Wormley.

Overall Comments

Once the leaks had been sealed the pitch-roll buoy worked very well. It turned over in very rough seas, but even then it could be launched and recovered safely and easily.

I.O.S. should not have become involved in the design and production of magnetic tape interfaces. The programming language, CATY, is too slow for data acquisition and in future alternative languages should be considered.

The waves during JASIN were shorter than expected but some good, and I hope eventually useful, data were obtained.

D.J. Webb

8. Shipborne Wave Recorder (P.G. Collar, D.J. Webb)

During Leg 2, the shipborne wave recorder was operated on several occasions when the cloverleaf buoy was deployed (Table 7). During Leg 3, the shipborne wave recorder was operated frequently, once to intercompare with JOHN MURRAY (day 234), most often to coincide with pitch-roll buoy deployments (cf Table 6).

R.T. Pollard

9. Cloverleaf buoy (P.G. Collar, C.H. Clayson)

Leg 2.

Experiments were done in conjunction with the tracking of transponding floats (P.M. Saunders) to examine the feasibility of measuring near-surface mean currents from a surface following buoy. Five comparisons were made between currents recorded at 1 m depth by vector averaging electro-magnetic current meters (VAECM) mounted rigidly on an IOS cloverleaf wavebuoy and the rate of displacement of the buoy from a transponding float drogued at 1 m depth. A similar transponder tethered to the wavebuoy enabled the buoy position to be obtained simultaneously with that of the floats.

Several deployments were made (Table 8) to test for consistency and coherence in data obtained from similar current sensor heads in differing wave conditions; subsequently to asses any effects attributable to head response by using two types of head. With one exception, when a $4m^2$ drogue was attached at 25 m by a compliant line, the buoy and tethered transponder were allowed to drift for some hours downwind from the drogued surface float before recovery.

P.G. Collar

10. Computer Group (B. Lewis, J. Burnham, G. Yarwood, D. Collins)

Leg 1. PDP 11/34 Data Logging System

In the first few days of the cruise, connections were completed to instruments and computer peripherals, and software written and modified to allow sampling of raw data from:-

1. C.T.D. (16 per second)
2. Surface Temperature (16 per second)
3. EM Log and Gyro (1 per second)
4. LORAN receiver (1 per second)
5. Satellite Navigation system.

In parallel with sampling, programs were run to calibrate and condense CTD, surface temperature and relative navigation data, to extract position fixes from LORAN data, to archive raw and processed data to magnetic tape, and to display data on 2 VDUs.

The system worked as expected, with the exception of the interface to EM Log and gyro which introduced spikes into the data. With all sampling and processing programs running, the system could just keep up with plotting requirements on the VDUs. Towards the end of the Leg, Batfish runs were successfully logged using the system, with the exception of EM Log and Gyro (the interface has a hard fault).

B. Lewis

Satellite Navigation (P. Hartland)

The MX702A receiver proved very troublesome after the Pre-JASIN port of call at Barry, and was not operating for 4 days.

A pattern of confused symptoms occurred. The crystal oscillator, power supplies and IPDH boards were changed, significantly improving the failure rate of the self test.

However, one persistent fault remained, in that the receiver would perform the self test if disconnected from the computer but would immediately 'unlock' as soon as the program was in a 'run'.

This fault, originally thought to be in a faulty cable, was finally found to be a faulty CIM (Computer interface) board.

The down time could have been reduced if a reply from Barry had been quicker (7 days).

The 'Old' stand-by system was used for the period in which the 'New' system was down. An intermittant problem with the Low doppler channel DPU was found and cured, but a great majority of the fixes were of dubious quality.

1800 System (P. Hartland, J. Burnham, G. Yarwood)

This performed well without any hardware problems.

Two spare DL91 interfaces were built and tested, for the 11/34 system. A modification to two of these interfaces enables IBM compatible outputs to be used.

An unsuccessful attempt was made to log the LORAN on the 1800 system using the front end computer as an interface.

A CATY program was used to output re-formatted LORAN channels on demand from the 1800. These were read in as groups of two 1½ words (6 BCD digits). Due to the lack of time it was not possible to modify the 1800 software to calculate a fix from these values, but it would seem to be a relatively easy problem given sufficient time.

The air conditioner water pump fractured allowing water to escape in the forward hold. This was not noticed until the computer room was significantly warmer.

As there is no pressure alarm fitted to the pumps about six inches of water was found to be in the hold. This could be potentially dangerous as a large amount of electrical gear is installed in this area. A pressure alarm in the computer room with an isolator would improve this.

P. Hartland

Leg 1. (G. Yarwood)

The IBM 1800 system was run to provide track plots and profiles of meteorological parameters to meet the scientific requirements on the cruise. The profile plotting program was further modified for the special needs of the JASIN experiment. A fault in the program for processing LORAN-C fixes off-line was investigated, and the possibility of interfacing the new LORAN receiver with the system was considered. The program for evaluating thermometer calibrations was run as required. On the whole, the system functioned satisfactorily, and no unusual problems were encountered.

Leg 2. (T. Colvin, S. Audley, J. Burnham, G. Yarwood)

The PDP 11/34 system operated continuously throughout the Leg, recording navigation data from the LORAN-C receiver and CTD data from the Batfish and surface temperature fish, as required by the scientific programme. No troubles were experienced with the system, except for two unexplained system crashes which are believed to have been due to program faults, possibly in that part of the DEC-supplied operating system which handles the operation of the interactive consoles. A minor calibration fault in the program which calculates the LORAN-C fixes was corrected shortly after leaving port.

It was clear that the system could be operated successfully without difficulty by the scientific users without assistance from the computer group. A complete set of operating instructions was prepared for the general user.

The PDP and CAMAC interface equipment and the RDL magnetic tape drives operated without any faults, as did the interfaces constructed by the computer group for the LORAN-C receiver and the surface temperature fish.

The IBM 1800 system was also operated continuously throughout the Leg, recording navigation data from logs, gyro and satellite receiver, as well as a range of meteorological parameters. A fault in the off-line LORAN fix calculation program was traced and corrected and the program was used daily to enable half-hourly LORAN fixes to be plotted on the satellite-corrected track for comparison purposes. Profiles of the meteorological parameters were plotted daily.

The programs for the shipborne wave recorder were run on several occasions to provide comparisons with data collected from pitch-roll buoys. The program for calculating paths of sound waves in surface layers of the sea was also run. Weekly plots of the meteorological parameters and of the ship's track were made.

The IBM equipment operated satisfactorily except for minor faults with one of the disc drives and the console printer which were corrected. Faults which developed in the associated equipment were dealt with. These faults were in the gyro interface cable, which led to loss of 24 hours of course-corrected data, and in one of the CAMAC interface modules.

The PDP-11/04 front-end computer was used for decoding data from the Clayson logger from pitch-roll buoys, the decoded data being written to magnetic tape. An interface was built to enable the tally printer to be driven from the 11/04 through the CAMAC paper tape punch interface to aid in programming the 11/04. A suite of programs was written to sample the LORAN-C from the new DL91 receiver on the PDP-11/04, passing the time differences and status to the IBM 1800 for calculation and plotting of the fixes.

A fault in the magnavox satellite receiver in the early part of the Leg was cured by replacement of the oscillator and substitution of the analogue circuit boards.

Leg 3. (B.W. Lewis, I.Innes, G. Knight, R.J. Burnham)

The third Leg of JASIN '78 saw the two PDP 11 machines and the IBM 1800 continually in use. The IBM 1800 provided daily and weekly navigation plots with an assortment of profile plots. The Shipborne Wave Recorder was used on several occasions, the IBM 1800 listing and punching the 1 second raw data. The programs developed during Leg 2 for inputting LORAN C fixes into the IBM 1800 were completed and the hardware built. This enabled 10 minute listings of the LORAN calculated ship position to be printed out on the main computer output printer. This involved using the PDP 11/04 machine as a front end processor.

The PDP 11/04 was also used to translate Pitch Roll Buoy data from magnetic cassette to 9 track magnetic tape. When not required for these two major roles it was used as an engineering diagnostic tool and as a development aid in interfacing a drum plotter to the PDP 11/34.

The PDP 11/34 was used continuously throughout the Leg to record, process and archive batfish data, surface temperature profiler data and navigation. Regular 10 minute hard copy plots of profiles, contours and navigation were taken.

B. Lewis

11. Meteorological Instruments (J. Moorey, G. Griffiths)

The scientific meteorological instruments functioned without interruption throughout the cruise, and maintenance was purely routine.

Observations, and comparison with the ship's instruments require the following notes to be made:

(1) Sea surface temperature

Generally, within +0.0 to +0.2°C of a bucket sample, measured to 0.02°C.

(2) Barometer

The instrument performed perfectly, but for a wind velocity dependant correction, amounting to -0.5mb at 30 knts. (Fig. 10.3)

(3) Air temperature thermometers

The dry bulb measurements were, on average, within +0.0 to -0.3°C of the bridge mercury thermometers. Compared with the mercury wet-bulb depression, the logged reading were on average 0.2°C greater (Figs. 10.1 and 10.4). Higher temperatures were noted during periods of a following wind, and should be treated with care.

(4) Anemometers

a) When the relative wind was from about 085° to 095° the instrument was, to a greater or lesser extent, stalled because of the wake of the 'A' frame mast.

(4) Anemometers (cont'd)

b) The instrument periodically showed a high threshold velocity of about 6 knts.

c) Compared with the bridge (starboard) anemometer, the port (logged) anemometer appeared to read low by approximately 15%. (Fig. 10.2)

(5) Solarimeter

This instrument gave no problems during the cruise.

G. Griffiths.

12. Navigation in the JASIN area (R.T. Pollard, Miss M.A. Saunders, R.J. Burnham)

Accurate relative navigation was critical during the JASIN cruise, as a major part of the scientific program was the tracking of floats and drifting current meter strings relative to the ship. Discovery's normal prime navaid is satellite, using a two-component electromagnetic (EM) log to interpolate between satellite fixes. However, LORAN-C, supplemented by the Hebridean Decca green lane was the preferred JASIN prime navaid and Discovery was newly fitted with a Decca LORAN-C DL91 Mk 2 system.

At the start of the cruise, Decca/LORAN triangles and satellite fixes were regularly plotted and compared (e.g. Figure 11). It appeared that:
(a) the Decca line always lay to the north of the LORAN fix, the mean difference between the Decca/SL3Y fix and the LORAN fix being about 300 m.
(b) The LORAN fix lay, in the mean, north-east of the satellite fix, the mean difference being 400-500 m, depending on how stringent were the conditions for rejecting satellite fixes.

These mean discrepancies suggest that lane corrections could be calculated to minimise the differences. Since our primary concern was relative navigation, this was not attempted. We were more concerned by the standard deviation of the differences between fixes. On a small sample (23) the Decca/LORAN versus LORAN differences had a standard deviation of about 300 m. The corresponding value for LORAN versus satellite was over 450 m, apparently due mostly to random errors in the satellite fixes. Accordingly, LORAN was selected as the more consistent navaid, and its problems were examined in detail.

The SL3-Y signal (master in Faeroes, slave in Iceland) was reliable at practically all times. The signal did not wander within the resolution of the readout (0.1 microsec. of order 30m in the JASIN area). (Fig. 12) and the sky wave warning light was only observed to be on during heavy rain.

The SL3-W signal (slave at Sylt in Germany) was weaker than the SL3-Y and showed a variety of problems (Figures 12 and 13):

(1) With the signal indicator on and no sky wave indicator, the readout still oscillated (Fig. 12) over a range of up to one microsecond, or 300 m, particularly at night between 2000 GMT and 0500 GMT. The oscillation had a period of order one minute, so one minute averages of one second sampled data were used for track plots.

(2) When sky wave was present the signal might jump by about ten microseconds. It usually jumped back again within a few minutes, and we believe such jumps can be edited out to a fraction of a microsecond.

(3) Occasionally, perhaps once a day on average, the SL3-W signal was weak enough that the system lost lock completely. It could usually be relocked by adjusting the notch filters to reduce noise on either side of the signal frequency band and by manually slewing the readout to about the right value.

Because of SL3-W problems, track plots based solely on LORAN (Fig. 14a) require editing and smoothing before they can be used for precise navigation. On <u>Discovery</u> we found that an alternative system, using EM log and gyro compass to interpolate between half hourly LORAN fixes, gave the best results (see following note on Navigation Procedure). The program used was identical to that used for satellite navigation. Whenever a satellite fix (or in our case half hourly LORAN fix) is received, the computer compares it with the dead-reckoned position obtained by EM log and gyro since the previously accepted satellite or LORAN fix. Since the difference between fixes gives ship velocity relative to ground ($\underline{v}_{s-g}$) and the EM log and gyro gives ship velocity through the water ($\underline{v}_{s-w}$), the difference $\underline{v}_{w-g}$ is an estimate of the surface current. The computer rejects the new fix if the current so calculated is larger than some user specified value, in our case one knot. If the current is less than one knot, the fix is accepted and the dead-reckoned positions (at two minute intervals) since the previous fix are corrected for the calculated mean current between the two fixes. A track plot by this method (Fig. 14b) is smoother than the LORAN plot and bad LORAN fixes due to sky wave or loss of lock are almost always rejected by the maximum current criterion.

Since the program produces an estimate of the surface current every time a fix is accepted, the relative accuracy of satellite versus LORAN navigation can be quantified by examining the time series of surface currents produced by each. The currents are plotted (Fig. 15) for day 250 (7th September). The ship was mostly hove to on that day, so that EM log calibration errors are minimised. An oscillation, probably of inertial period, is clearly resolved by the LORAN fixes, but rather poorly by satellite fixes. Noise on the LORAN current plot is less than about 0.2 kts. equivalent to 200m error in the difference between two fixes 0.5 hours apart. The currents derived from satellites are more sparse, with errors of 0.4 kts or more. The error between successive fixes an hour or more apart can therefore be 1000 m or more. Thus our impression that LORAN is a better navaid than satellites in the JASIN area is confirmed.

R.T. Pollard and Margaret Saunders

Navigation Procedure

During Leg 3 an off-line method of making LORAN-C the prime navigational aid was adopted using half-hourly LORAN fixes from the new LORAN DL91 receiver, with two minute DR positions from the E/M log and gyro. By so doing the superior position fixing of the LORAN-C for the area could be conveniently displayed using the standard IBM 1800 plotting software.

The criteria whereby a navigation source is made the prime navaid is decided at the start of a leg by the DEFINE NAVIGATION command of the sampling monitor program suite SAMON. Here, normally, the prime navaid is set to be satellite. The computer file FIXF is the file which holds all fix positions for a given day and time. In this file all satellites fixes have a word 7 fix type value of 1 whereas all LORAN-C off-line fixes have a word 7 value of 2. Without changing the prime navaid via SAMON, if the word 7 value for satellite and LORAN-C are swapped over, then LORAN-C disguised as satellite fixes are now the effective prime navaid. The program SYKEY very adroitly performs this manipulation.

The procedure then is as follows:-

1) Enter the LORAN-C positions into the file FIXF using the program HYCAL. The automatic course update switch must be turned off at this point.
2) Obtain a listing of the FIXF file for that day, using the program SYKEY.
3) As no course update has taken place the fixes are not in temporal order within the file and as such one command from SYKEY performs the alteration. Using SYKEY alter all the satellite fix word 7 FIXF values to 2. At the same time it is convenient to alter word 8 (quality assignment) to -4. Finally alter the LORAN-C fix word 7 values to 1.
4) Obtain a second listing of FIXF to check the results.
5) Now run the off-line course update program ONAVI in six hourly groups (i.e. from midnight to 0600 hrs., then again from 0600-1200 hrs. and so on for the whole day). This process normally takes about an hour to complete. If ONAVI is run for much longer than six hour groups the program crashes as array sizes are exceeded.
6) Normal track charts can then be produced with the program SMERQ remembering that the symbols for satellite and LORAN are reversed.

This method proved very successful during the cruise, so has been recorded for possible future use. Although the ability to input LORAN-C fixes into the FIXF file online was implemented during Leg 3, the offline method was preferred because (a) bad LORAN values could be rejected before input to the 1800 (b) it simplified the editing procedure (3 above) (c) the one-minute averages from the PDP 11/34 were marginally better (Fig. 12) than the one-second spot values the 1800 could provide.

R.J. Burnham

TABLE 1 - Drifting Spar P2 and Instrumentation

Mooring	257	258	259	260
Time set	1200/198	1200/210	1232/214	1131/220
Recovered	1109/201	1425/213	1302/219	0912/226
Duration	71.15 hours	76.42 hours	120.50 hours	141.68 hours
Position set	59°29.31'W 12°29.91'W	59°23.66'N 12°29.76'W	59°9.68'N 12°32.23'W	59°8.94'N 12°17.63'W
Recovered	59°27.66'N 12°48.49'W	59°30.35'N 12°15.97'W	59°7.34'N 13°31.26'W	59°32.84'N 13°3.26'W
Mean drift	7.1 cm/sec to 260°	6.6 cm/sec to 047°	13.1 cm/sec to 266°	12.2 cm/sec to 315°
Instrument depths	16, 20, 24, 36, 40, 44m	18, 25, 29, 33 40, 44, 48m	16, 21, 25, 29, 34, 38, 42m	14, 17, 21, 25, 28, 32, 36m
Instrumental notes: V = AMF VACM E = IOS electro-magnetic VACM Each box contains	16m, V430 2571 no data	18m, V430 2581	16m, V430 2591	14m, V132 2601 15% data loss
	20m, V429 2572 no data	25m, V159 2582	21m, V159 2592	17m V429 2602
depth instrument number record data quality where known	24m, V156 2573	29m, E1 2583 includes vertical velocity	25m, E1 2593 includes vertical velocity	21m, E2 2603
	36m, V159 2574	33m, V132 2584	29m, V156 2594	25m, V156 2604
	40m, V132 2575 bad until 1400/199	40m, V429 2585	34m, V429 2595	28m, V430 2605
	44m, V130 2576 a few bad values	44m, E2 2586 noisy, no vertical	38m, E2 2596 poor quality no vertical	32m, E1 2606 only vertical velocity usable
		48m, V156 2587	42m, V132 2597	36m, V159 2607

TABLE 1 - Drifting Spar P2 cont'd

Mooring	261	262	263	264
Time set	1443/235	0801/241	0901/245	1612/252
Recovered	0935/239	1559/244	0909/251	1555/257
Duration	90.87 hours	79.97 hours	144.13 hours	119.72 hours
Position set	59°07.57'N 12°34.00'W	58°56.25'N 12°25.74'W	59°29.21'N 12°40.54'W	59°09.24'N 12°34.43'W
Recovered	58°59.77'N 12°49.91'W	58°48.15'N 12°03.37'W	59°17.11'N 13°07.42'W	59°08.33'N 12°25.15'W
Mean Drift	6.4 cm/sec to 226°	9.1 cm/sec to 125°	6.6 cm/sec to 229°	2.1 cm/sec to 101°
Instrument Depths	14,16,21,25, 29,34,38,42m	14,16,23,27, 31,38,42,46m	14,16,21,25 29,34,38,42m	14,16,23,27, 31,38,42,46m
Instrumental notes V = AMF VACM E = IOS electro-magnetic VACM	14m, V130 2611	14m, V130 2621	14m, V130 2631	14m, V130 2641
	16m, E3 2612	16m, E3 2622	16m, E3 2632	16m, E3 2642
	21m, V429 2613	23m, V429 2623	21m, V429 2633	23m, V430 2643
	25m, E1 2614	27m, E2 2624	25m, E2 2634	27m, E2 2644
	29m, V156 2615	31m, V159 2625	29m, V159 2635	31m, V156 2645
	34m, V430 2616	38m, V430 2626	34m, V430 2636	38m, V429 2646
	38m, E2 2617	42m, E1 2627	38m, E1 2637	42m, E1 2647
	42m, V159 2618	46m, V156 2628	42m, V156 2638	46m, V159 2648

TABLE 2a - Float Tracking - DISCOVERY 94 Leg 1

START			STOP			Experiment { Measurement Depths, M					Supporting Measurements
Time Day	LAT.	LON.	Time Day	LAT.	LON.	Shear		Pressure Telemeter PT			
18-7 1646/199	59 28.66	12 37.35	2057/199	59 28.70	12 37.98			300			
20-7 1020/201	59 27.71	12 47.75	1940/201	59 27.97	12 50.72			150(after 30gm added)			
20-7 2300/201	59 28.4	12 51.3	21-7 0700/202			1,2,10	(1m	failed to transpond)			
21-7 2130/202	59 23.5	12 32.1	22-7 0700/203			1,2,10					0321-0706 Pitch Roll Buoy near H2

A free drifting Dan buoy with radar reflector supported the remote interrogator at 10m. With the ship's interrogator it formed the baseline for acoustic navigation of the floats. The bearing of the Dan buoy was measured by ship's radar.

TABLE 2b - Float Tracking - Leg 2

START			STOP			EXPERIMENT AND { MEASUREMENT DEPTHS, M					
Time Day	LAT	LON	Time Day	LAT	LON	Shear	Dispersion No.	Pressure Tele-meter PT	Clover-Leaf (or spar) INTCMP	Aid to Launch Spar	Supporting Measurements
29-7 1510/210	59 23.4	12 27.1	30-7 0900/211			1,2,10					0430-0700 Pitch Roll buoy
30-7 1400/211	59 25.9	12 26.7	31-7 0800/212			1,10	(3) 10				
1-8 2008/213	59 00.1	12 45.6	2-8 0955/214	59 00.3	12 58.2			170			
2-8 1800/214	59 10.6	12 34.5	3-8 0730/215			1,2,25			1(25)		1850-1915 & 2215-2240 Shipborne Wave recorder.
2-8 2230/214	59 10.9	12 39.0	3-8 1011/215				(5) 1				
5-8 1600/217	59 12	13 15	6-8 0800/218			1,2,10, 25			(25)		
6-8 1430/218	59 09	13 25	7-8 0800/219			1,2,10 25			1(25)		1517-1552 & 2335-0145, Shipborne Wave Recorder, 2130-2330 Pitch Roll Buoy.
7-8 2152/219	59 08.1	11 53.2	8-8 0824/220	59 06.2	11 54.5					10	

TABLE 2b - Float Tracking - Leg 2 (cont'd)

START			STOP			EXPERIMENT AND MEASUREMENT DEPTHS, M					
[illegible] DAY	LAT	LON	TIME DAY	LAT	LON	Shear	Dispersion (Number)	Pressure Telemeter PT	Cloverleaf (or spar) INTCMP	Aid to launch Spar	Supporting Measurements
[illegible]			2012/221	59 12.0	12 32.4				(25)		
[illegible]/224	59 25	13 04	13-8 1900/225			1,3,10, 25.			1 (25)		1055-1122 and 1145-1202 Shipborne Wave Recorder
[illegible]	[illegible] 25.0	13 07.2	0903/225	59 25.9	13 09.5			20			
[illegible]	[illegible]	13 09.0	1547/225	59 27.0	13 12.5			250			
[illegible]	59 26	13 08	1830/225			1,25			1 (25)		1238-1256 Shipborne Wave Recorder.
[illegible]	59 30.50	13 09.24	14-8 0700/226	59 32.88	13 08.14			30			
[illegible]	[illegible] 30.51	13 09.20	14-8 0730/226	59 32.34	13 07.40			80			
[illegible]	[illegible] 00.2	12 45.2	2-8 0912/214	59 00.3	12 58.2					10	
[illegible]	[illegible] 25.11	13 07.10	13-8 0928/225	59 26.09	13 09.32				(25)		

[illegible] 10m below a Dan buoy (with radar reflector) was tethered to Spar buoy P2. With the ship's [illegible] fish) it formed the baseline for acoustic navigation of floats. The bearing of the Dan [illegible] by ship's radar.

TABLE 2c - Float Tracking - DISCOVERY 94 Leg 3.

START			STOP			EXPERIMENT AND MEASUREMENT DEPTHS, M					
[illegible]	LAT, N.	LON, W.	Time Day	LAT, N	LON, W.	Shear	Dispersion (Number)	Pressure Telemeter	SPAR current INTCMP	Aid to Launch SPAR	Supporting Measurements
[illegible]	[illegible] 09.00	12 26.61	23-8 1230/235	59 05.74	12 30.02					10	
[illegible]	[illegible]	12 34	24-8 0900/236			1,3,10 25.			25		1130-1430 Pitch Roll Buoy
[illegible]	59 0[illegible]	12 37	25-8 1800/237			1,3,10 25			25		1100-1400 Pitch Roll Buoy
[illegible]	[illegible] 59.80	12 46.15	26-8 1428/238	58 59.80	12 45.47			250m (malfunction)			
[illegible]	[illegible].12	12 20.74	28-8 1724/240	58 54 01	12 17 06					25	
[illegible]	58 57.07	12 31.20	2210/240	58 54.47	12 29.13					25	
[illegible]	58 5[illegible].[illegible]	12 40.73	1939/240	58 54.95	12 42.65					25	
[illegible]	[illegible].36	12 31 01	29-8 0858/241	58 51.05	12 27.86			~ 45			CTD Station 9839
[illegible]	58 55.46	12 30.52	28-8 2138/240	58 54.30	12 29.23			~ 45			
[illegible]	[illegible] 51.5	12 09.2	1-9 0700/244			1,3,10, 25.	(10m lost at 1930 replaced 2100)				1240-1540 Pitch Roll 0509-0548 CTD 9841

TABLE 2c - Float Tracking - DISCOVERY 94 Leg 3 (cont'd)

START			STOP			EXPERIMENT AND MEASUREMENT DEPTHS, M					
Time Day	LAT, N.	LON, W.	Time Day	LAT, N.	LON, W.	Shear	Dispersion (Number)	Pressure Tele- meter	SPAR curr- ent INTCMP	Aid to Launch SPAR	Supporting Measurements
1-9 0910/244	58 48.11	12 03.33	1532/244	58 48.35	12 03.54			5			
0912/244	58 48 12	12 03.39						70			CTD 9842
1-9 2200/244	59 24.30	12 29.78	1-9 0659/245	59 21.65	12 27.47					25	
6-9 1830/249	59 15.1	13 03.2	7-9 0830/250			1,3,10, 25			25		XBT 9842-48
7-9 1025/250	59 18.55	13 08.59	1738/250	59 17.04	13 04.15			40			XBT 9849-51
1032/250	59 18.59	13 08.36	1645/250	59 18.10	13 06.00			40			
1900/250	59 15.9	13 06.8	8-9 0830/251			1,3,10 25			25		XBT 9852-57 0740-1030 Pitch Roll
8-9 2012/251	59 10.59	12 39.29	9-9 1418/252	59 07.19	12 46.27			40			XBT 9861-72 CTD 9871
12-9 1537/255	59 06.8	12 39.0	13-9 0700/256			1,3,10, 25			25		XBT 9873-88 0500 Ship wave recorder
13-9 1041/256	59 09.29	12 32.82	Last 1715/256	Not recovered				40-60			XBT 9889-9903 1500 Ship wave recorder

TABLE 2c - Float Tracking - DISCOVERY 94

Leg 3 (cont'd)

At 0905 on 4-9-78/247 Remote Interrogator was recovered and found flooded. It was replaced at 10m under Dan buoy by 1300 the same day. See note at end of Leg 2 for method of navigation.

TABLE 3 - Batfish Tow Summary

(Y = fast yoyo, S = slow yoyo, H = horizontal tow)

Run Number	Pattern and Depth Range (m)	Start	Stop	Duration (hours)	Comment
1-2	Y 8-70 H 18,30,60	1000/199	1630/199	6½	E, W test runs N of H2
5-14	Y 5-75	1142/203	0804/204	20½	Section on passage from H2 via P1 towards Glasgow
15-23	Y 5-80	1030/212	1253/213	25	Triangular runs round P2 near H2
24	Y 4-80	1329/214	1537/214	2	Survey square close to B4
25-30	Y 4-80	1233/215	0523/216	8	Squares round P2 drifting W of B4.
31-42	H 6,15,20	0529/216	1250/217	26	Several interruptions
43	Profile 120m	1253/217	1316/217	½	
44-49	Y 3-80	1405/219	0711/220	15½	Survey round FIA and to N and E.
51-53	Y 3-80	1253/220	1844/220	4½	2 Squares round P2 near B4
54-82	H 6,15,20,25 S10-35 Y 5-50	0523/221	0541/224	66½	Squares round P2 drifting W from B4, wind 10-15 kts then 20-25 kts.
84-87	Y 3-80	1120/234	0221/235	13½	Section on passage Glasgow to John Murray (59°46'N, 12°30'W) then S to B4.
88-91	Y 3-80	2341/237	1056/238	11	2 mapping runs around FIA.
92-96	H 25,50,75 Y 3-50	2237/238	0856/239	10	Squares round P2 W of W3
99	Y 3-55	2256/240	2341/240	1	Test run radar marker to Meteor
100-111	Y 5-50	1043/241	1048/242	24	Squares round P2 SE of FIA First multi-ship experiment.
112-123	Y 3-50	1648/242	1149/243	19	Mapping NS parellel legs round S and SE of FIA.
124-143	S 0-25 Y 2-40	2245/244	1740/246	38½	5½ Kt. squares round H2 before, during and after 2nd multiship experiment. Alternate circuits fast and slow yoyos.
145-162	S 0-25 then S 5-50 one Y 1-40	1934/246	0640/248	31	Squares round P2 S & W of H2 position, wind up to 25 kts.
169-179	S 0-45	1834/248	1700/249	20½	Continuing after wings mended.
181-183	Y 5-70	1301/251	1925/251	6½	Survey round A. Vernadsky, Planet, Tydeman, Challenger.
185-205	S 5-50 S15-50	1643/252	1404/255	69½	21 circuits of elongated triangle (030°, 185° 235° along swell) round P2 near B4 position, wind up to 30 kts., cooling.

TABLE 4(a) Lowered CTD Profiles (Leg 1)

Station Number	START		STOP		AT BOTTOM			Water Depth, M	Bottles/Thermometers
	Date	Time	Date	Time	LAT. N	LON. W	Press, DB		
9829	15-7/196	0135	15-7/196	0308	58 30.1	12 30.9	1593	1646	6/0
9830	15-7/196	0600	15-7/196	0604	58 46.0	12 33.7	1598	1661	3/0
9831	15-7/196	2333	16-7/197	0047	59 14.8	12 31.4	1461	1499	6/2
9832	16-7/197	0232	16-7/197	0407	59 02.6	12 31.6	1491	1536	3/0
9833	16-7/197	1343	16-7/197	1437	59 27.0	12 28.9	1337	1390	0
9834	16-7/197	2258	17-7/198	0003	59 46.0	12 29.4	1243	1288	5/0
9835	17-7/198	0226	17-7/198	0319	59 30.4	13 02.1	1258	1305	3/0
9836	17-7/198	0622	17-7/198	0705	59 29.4	12 01.2	1462	1510	3/0
9837	18-7/199	0007	18-7/199	0410	59 29.2 59 28.3	12 33.2 12 34.2	200 x 4 100 x 9		YOYO

TABLE 4(b) Lowered CTD Profiles - YOYO

(Leg 3)

Station Number	START				STOP				Depths DB	Close to
	Date	Time	LAT. N.	LON. W.	Date	Time	LAT. N.	LON. W.		
9838	26-8/238	1631	59 00.3	12 45.8	26-8/238	1938	58 59.7	12 46.8	0-100	P2
9839	28-8/240	1529	58 56.8	12 29.3	28-8/240	1559	58 55.0	12 29.1	0-100	2 PT Floats*
9840	29-8/241	0120	58 57.2	12 25.3	29-8/241	0559	58 57.5	12 27.1	0-100+	Planet and Meteor
9841	1-9/244	0509	58 51.2	12 04.1	1-9/244	0545	58 49.5	12 03.4	0-100	Floats 1, 3, 10, 25m.
9842	1-9/244	1335	58 48.8	12 04.2	1-9/244	1359			0-100	2 PT Floats
		1416				1433	58 48.5	12 03.0		
9871	9-9/252	0920	59 07.4	12 44.1	9-9/252	1000			0-100	
		1028				1106			and	PT Float
		1143				1250	59 06.5	12 46.5	30-60	

* Pressure telemetering

\+ At 10 minute intervals

TABLE 5 - 450M XBT LOG

Station Number	Date	Day	Time, Z	(Loran) LAT, N	LON, W	Station Number	Date	Day	Time, Z	(Loran) LAT, N	LAT, W
9843	6-9-78	249	1803	59 14.8	13 03.2	9875	12-9-78	255	1800	59 07.7	12 37.1
9844			2100	59 16.3	13 04.3	9876			1900	59 07.5	12 36.4
9845	7-9-78	250	0000	59 16.34	13 02.95	9877			2000	59 07.2	12 36.6
9846			0301	59 16.3	13 04.6	9878			2100	59 07.2	12 37.1
9847			0600	59 16.8	13 08.5	9879			2200	59 07.3	12 37.3
9848			0901	59 18.5	13 09.0	9880			2300	59 07.1	12 36.7
9849			1200	59 18.9	13 06.8	9881	13-9-78	256	0000	59 07.4	12 36.7
9850			1500	59 18.0	13 05.3	9882			0100	59 07.9	12 36.0
9851			1811	59 15.8	13 07.1	9883			0200	59 08.2	12 35.7
9852			2100	59 17.1	13 08.5	9884			0300	59 08.5	12 35.1
9853	8-9-78	251	0000	59 19.4	13 09.1	9885			0400	59 08.7	12 34.3
9854			0300	59 19.5	13 05.4	9886			0500	59 08.8	12 33.7
9855			0600	59 17.6	13 06.2	9887			0600	59 09.1	12 33.0
9856			0848	59 17.0	13 06.0	9888			0700	59 08.7	12 32.3
9857			1200	59 16.6	13 09.1	9889			1500	59 09.9	12 33.5
9858			2100	59 10.2	12 39.7	9890			1600	59.10.1	12 33.3
9859			2200	59 10.3	12 40.0	9891			1700	59 09.8	12 33.2
9860			2300	59 10.2	12 40.6	9892			1800	59 11.1	12 29.1
9861	9-9-78	252	0000	59 10.15	12 41.4	9893			1900	59 10.4	12 28.7
9862			0100	59 10.0	12 42.6	9894			2000	59 10.2	12 28.1
9863			0200	59 10.2	12 43.1	9895			2104	59 09.3	12 28.5
9864			0300	59 10.4	12 43.3	9896			2200	59 10.8	12 24.1
9865			0400	59 10.7	12 43.1	9897			2300	59 10.9	12 25.6
9866			0500	59 09.9	12 43.1	9898	14-9-78	257	0000	59 09.8	12 26.6
9867			0600	59 09.4	12 42.4	9899			0100	59 09.3	12 27.4
9868			0700	59 09.0	12 42.1	9900			0200	59 08.6	12 29.7
9869			0800	59 07.7	12 42.7	9901			0300	59 09.0	12 25.4
9870			0900	59 07.5	12 43.5	9902			0400	59 08.8	12 25.9
9872			1403	59 07.3	12 46.4	9903			2000	59 11.0	12 31.5
9873	12-9-78	255	1600	59 07.6	12 38.6						
9874			1700	59 07.5	12 37.8						

TABLE 6 - Pitch and Roll buoy deployments

Day	Date	Lat.	Long.	Time	Purpose	
LEG 1						
195	14 July	-	-	-	Trial - O.k.	
197	16 July	59°03.8'N	12°29.5'W	0205-0557	Alt.	
198	17 July	-	-	-	No vertical accelerations	
201	20 July	59°26.6'N	12°49.3'W	1236-1637	A, but no aircraft	
201	20 July	-	-	-	poor data	
203	22 July	59°26.8'N	12°32.2'W	0315-0700	Alt.	
LEG 2						
211	30 July	59°23.9'N	12°25.9'W	0430-0700	Alt.	
212	31 July	59°31.2'N	12°20.6'W	2100-2300	Alt.	
214	2 Aug.	58°59.4'N	12°51.4'W	0400-0600	Alt.	
215	3 Aug.	59°11.7'N	12°52.7'W	2130-2330	Alt.	
217	5 Aug.	59°09.2'N	13°11.5'W	0500-0700	Alt.	
218	6 Aug.	59°09.1'N	13°25.6'W	2130-2330	Alt.	
220	8 Aug.	59°08.3'N	12°18.7'W	1030-1230		
220	8 Aug.	59°10.1'N	12°24.0'W	1548-1600		
221	9 Aug.	59°11.8'N	12°34.6'W	2130-2330	Alt.	
LEG 3						
236	24 Aug.	59°02'W	12°37'W	1134-1419	A	
237	25 Aug.	59°01'W	12°42'W	1100-1400	A	W
242	30 Aug.	58°54'W	12°26'W	1130-1530	A	W
243	31 Aug.	58°52'W	12°09'W	1240-1540	A	W
244	1 Sept.	58°49'W	12°03'W	1210-1450	A	W
248	5 Sept.	59°11'W	12°41'W	0710-0810*	S	
251	8 Sept.	59°16'W	13°06'W	0740-1030	S	W

A = Aircraft Pass

Alt = SEASAT Altimeter

S = Synthetic Aperture Radar (SAR) Pass

W = Shipborne wave recorder operating

* = Only 2½ minutes of data, see text.

TABLE 7 - Shipboard Wave Recorder Runs

LEG 2

Run	Start	Stop	Comment
*1	18.50/214	19.15/214	Runs were made concomitantly with IOS Cloverleaf buoy drift. For positions see Cloverleaf buoy data inventory sheet.
*2	22.15/214	22.40/214	
*3	15.17/218	15.52/218	
+*4	23.35/218	01.45/219	
*5	10.55/224	11.12/224	
6	11.45/224	12.02/224	
7	12.38/225	12.56/225	

* Analogue record only

+* Possibly partly invalid due to occasional ship movements.

LEG 3

Day	Time	Position		Significant Height	Significant Period	Spectral Width
		N	W	M	Secs.	
234	2115-2133	59°45'	12°29'	2.1	5.8	0.42
236	0452-0509	59°05'	12°36'	3.2	7.5	0.59
237	1146-1203	59°01'	12°42'	2.7	6.9	0.56
242	1310-1327	58°54'	12°24'	1.2	5.9	0.51
243	1430-1442	58°51'	12°09'	2.3	6.1	0.46
244	1240-1257	58°48'	12°05'			
248	0930-0947	59°14'	12°49'	4.2	7.0	0.46
250	0507-0525	59°16'	13°7'	2.6	6.2	0.46
251	0015-0033	59°19'	13°9'	5.7	9.9	0.72
251	0814-0831	59°16'	13°8'	5.0	8.6	0.60
256	0500-0517	59°8'	12°33'	5.6	9.8	0.72
256	1159-1216	59°8'	12°33'	8.6	10.2	0.66
256	1528-1545	59°9'	12°33'	9.9	10.8	0.66
256	1800-1817	59°11'	12°29'	8.2	10.2	0.66
256	2100-2117	59°9'	12°29'	8.9	10.5	0.66
257	0000-0017	59°9'	12°26'	7.8	9.7	0.63
257	0300-0317	59°9'	12°25'	7.5	10.2	0.67
257	0600-0617	59°9'	12°26'	7.5	9.3	0.60
257	0859-0916	59°9'	12°27'	7.4	9.1	0.57
257	1200-1217	59°7'	12°38'	7.2	9.2	0.59

TABLE 8 - Cloverleaf Buoy Deployments

Run	Start-End	Latitude, N	Longitude, W	Description
1	16.34/214 07.45/215	59°10.55' 59°09.97'	12°34.42' 12°46.14'	Two VAECMs - discus head
2	13.53/218 08.55/219	59°11.87' 59°08.14'	13°26.08' 13°29.59'	One VAECM - discus head
3	10.16/224 13.40/224	59°24.28' 59°24.83'	13°03.85' 13°04.69'	Two VAECMs - discus head
4	14.12/224 20.30/224	59°24.97' 59°25.56'	13°06.11' 13°05.62'	Two VAECMs - discus head
5	10.39/225 19.30/225	59°26.54' 59°31.53'	13°08.53' 13°09.69'	Two VAECMs - discus head annular head

Buoy free drifting except for run 2 when it was drogued at 25m.

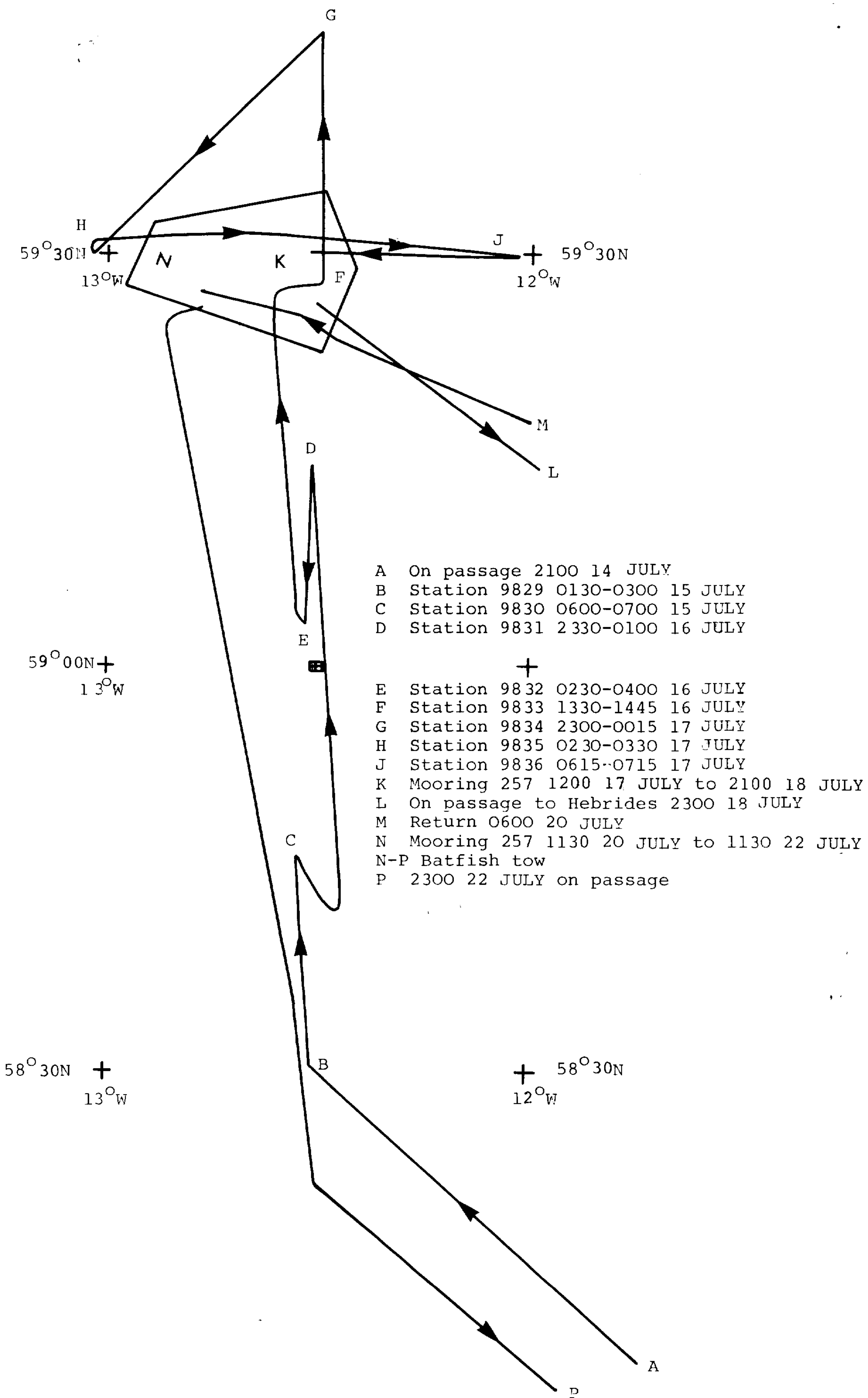


Fig. 1 Track plot - leg 1 - 2100/14 JULY - 2300/22 JULY

A On passage 0200 29 JULY
B Mooring 258 1000 29 JULY to 14 30 1 AUG.
C 1930 1 AUG.
D 1000 2 AUG.
E Mooring 259 1230 2 AUG. to 1330 7 AUG.
then see fig. 3.

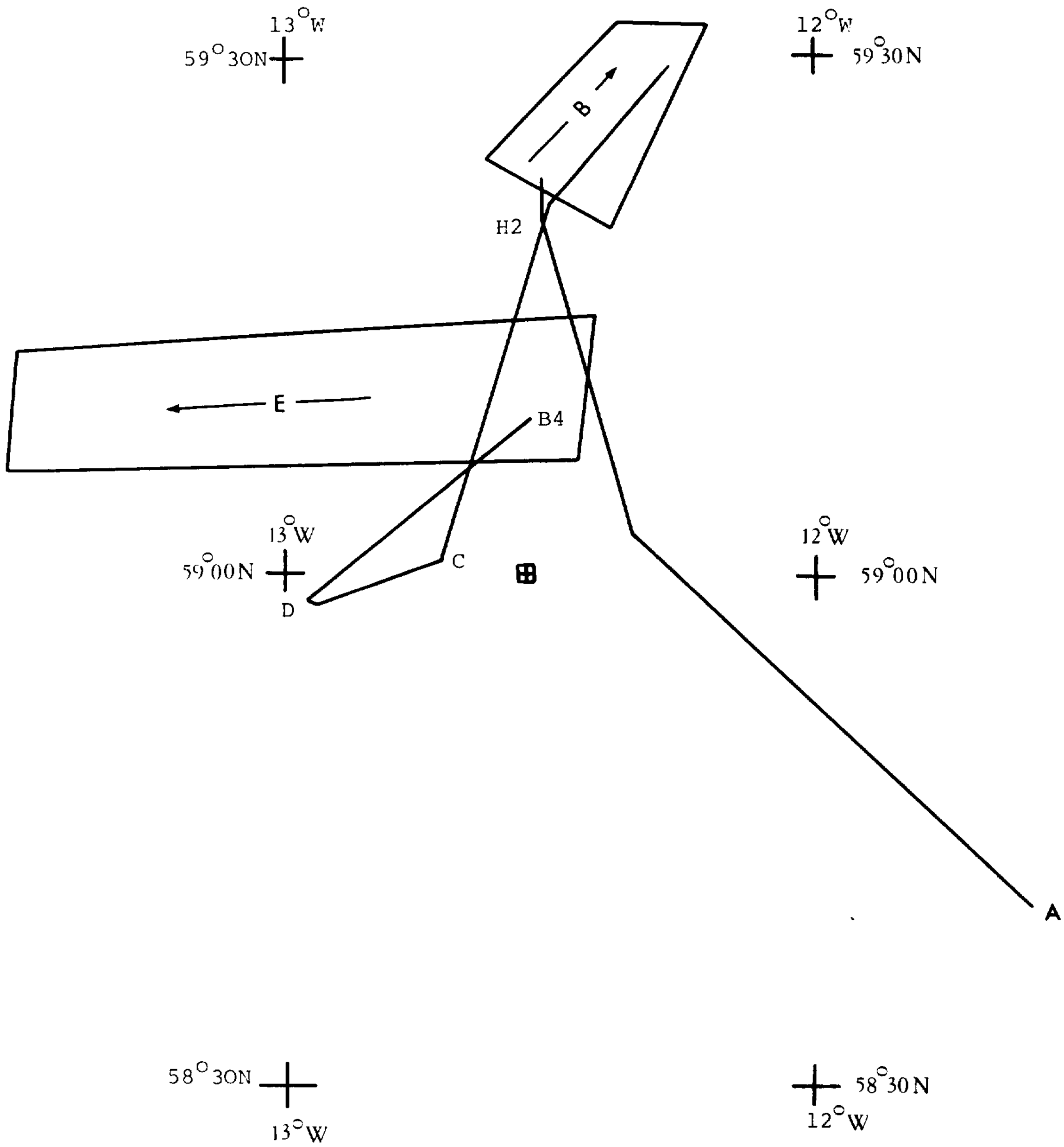


Fig. 2 Track plot - leg 2 - 0200/29 JULY - 2300/ 22 JULY.

A-E Batfish tow around FIA ⊞
A 1400 7 AUG.
B 2200 7 AUG.
C 0000 8 AUG.
D 0315 8 AUG.
E 0800 8 AUG.
F Mooring 260 8 AUG. to 0940 14 AUG.
G On passage 1400 14 AUG.

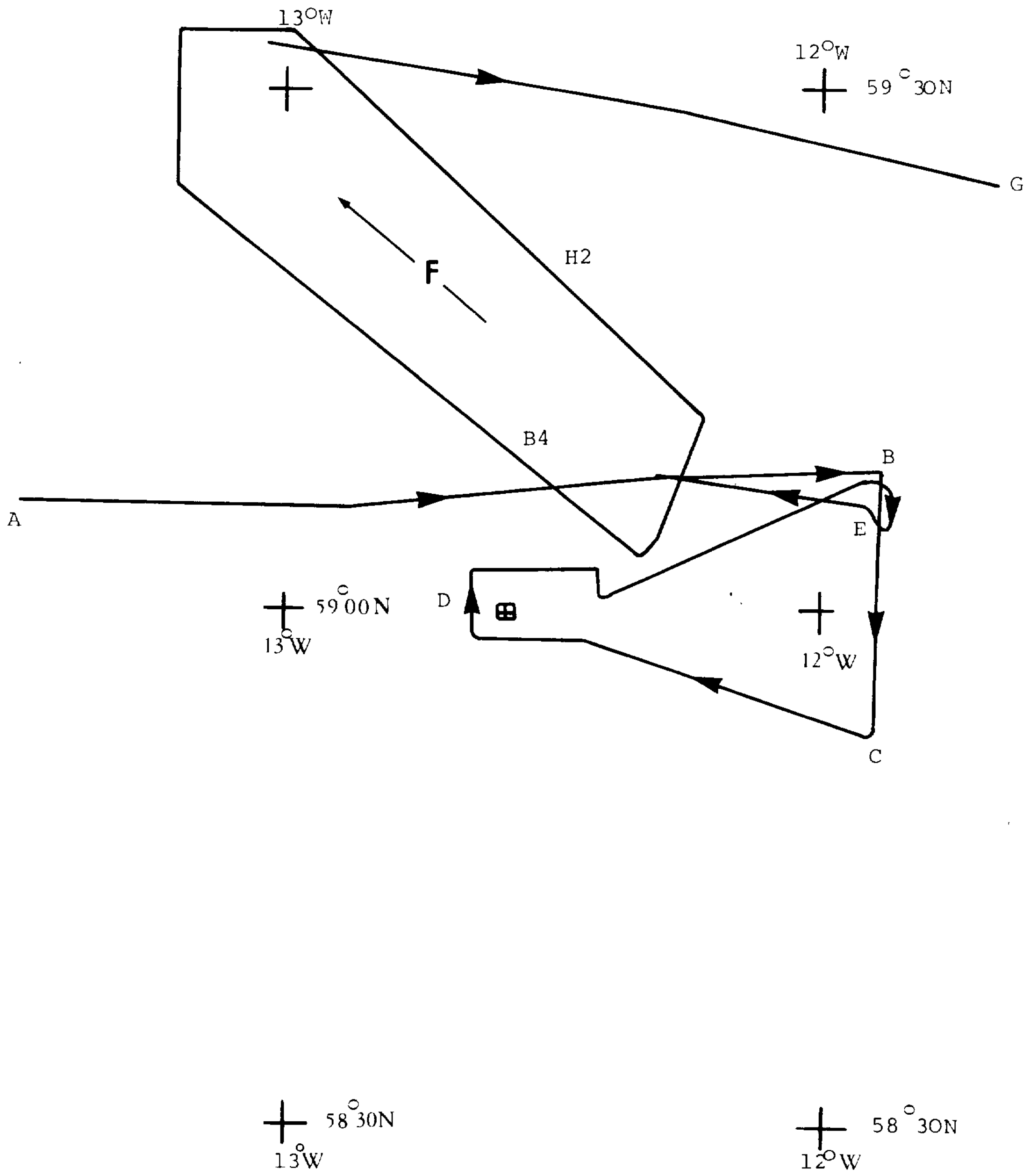


Fig. 3 Track plot - leg 2 - 1400/7 AUG - 1400/14 AUG

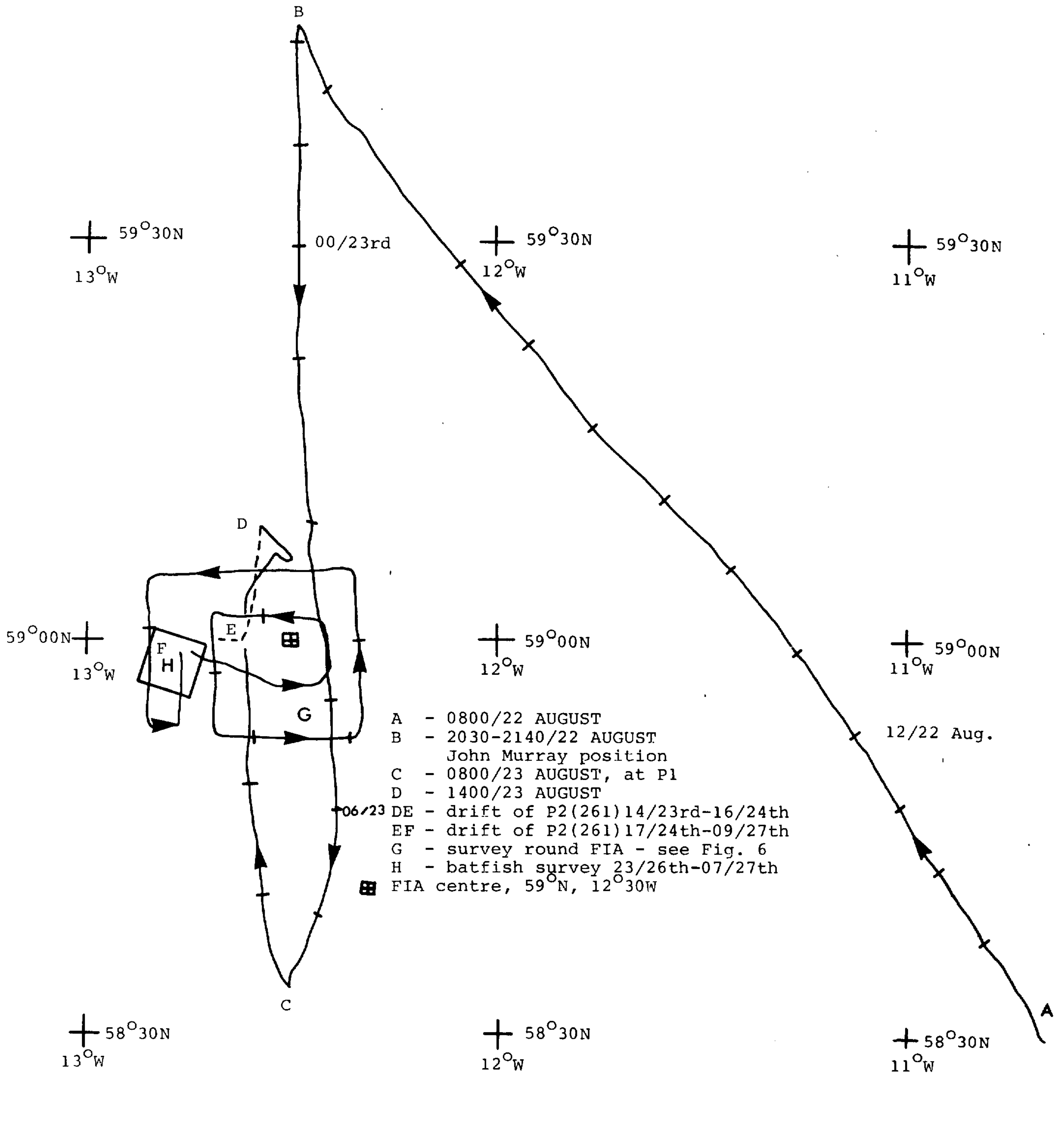
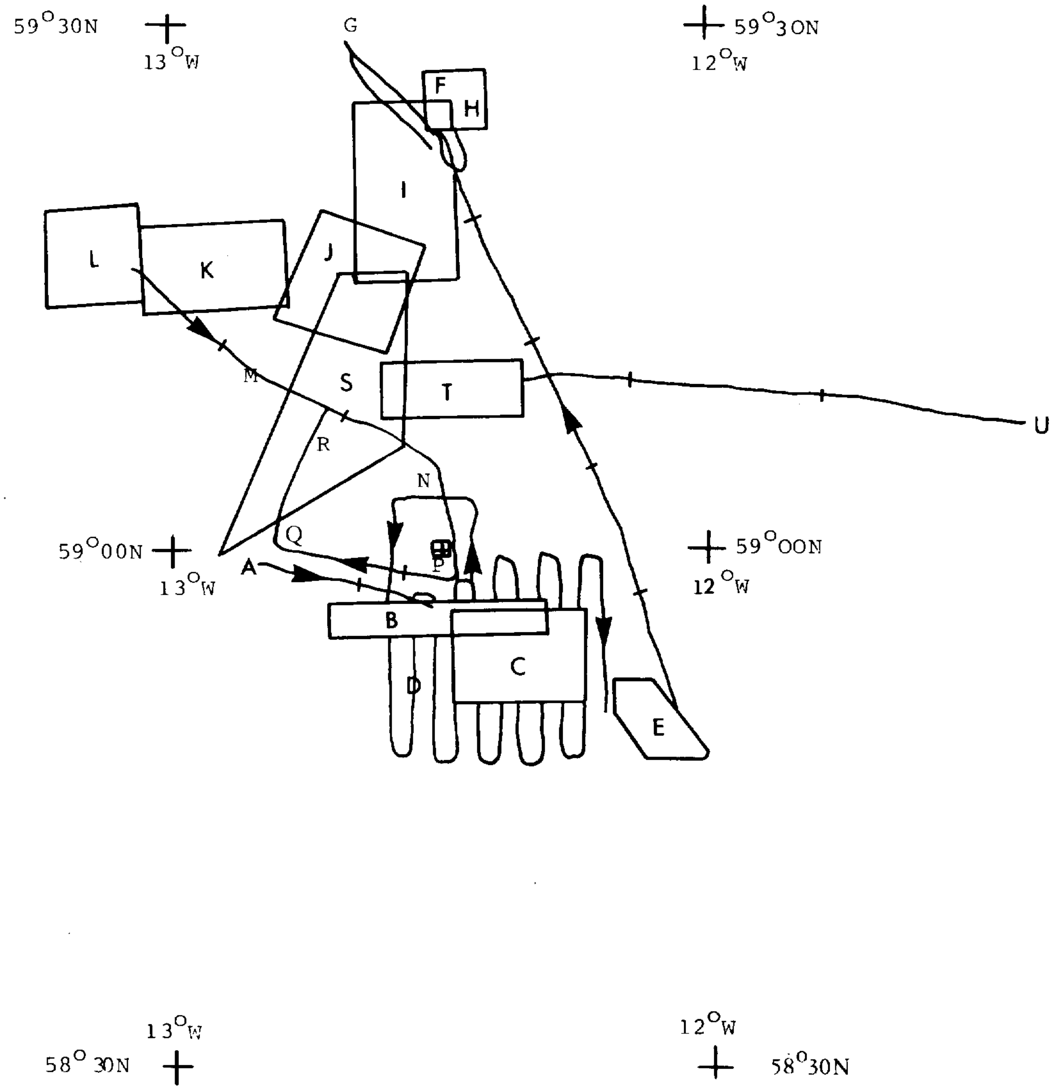


Fig. 4 Track plot - leg 3 - 0800/22 AUG - 0900/27 AUG.



A - recover spar - 0900/27-1000/27 AUG
B - float tracking - 1200/27-0800/29 AUG
C - survey - fig. 7 - 0800/29-1630/30 AUG
D - survey - fig. 8 - 1630/30-1200/31 AUG
E - float tracking - 1200/31 AUG-1630/1 SEPT
F - batfish survey - 2200/1-0600/2 SEPT
G - launch P2 (263) - 0900/2 SEPT
H - survey - fig. 9 - 1030/2-1720/3 SEPT
I - batfish survey - 1900/3-1700/4 SEPT
J - batfish survey - 1700/4-0630/5 SEPT
K - batfish survey - 1800/5-1700/6 SEPT
L - float tracking - 1800/6-1230/8 SEPT
GIJKL - drift of P2 (263)
LMNPQR - batfish round third multiship array
M - pass A. Vernadsky - 1430/8 SEPT
N - pass Planet - 1540/8 SEPT
P - pass Tydeman - 1630/ 8 SEPT

Q - pass Challenger 1800/8 SEPT
R - float tracking 1930/8-1420/9 SEPT
S - batfish survey round P2 (264)
1600/9 - 1400/12 SEPT
T - float tracking 1500/12-1700/14 SEPT
later hove to.
U - on passage 0000/15 SEPT

Fig. 5 Track plot - leg 3 - 0900/27 AUG - 0000/15 SEPT.

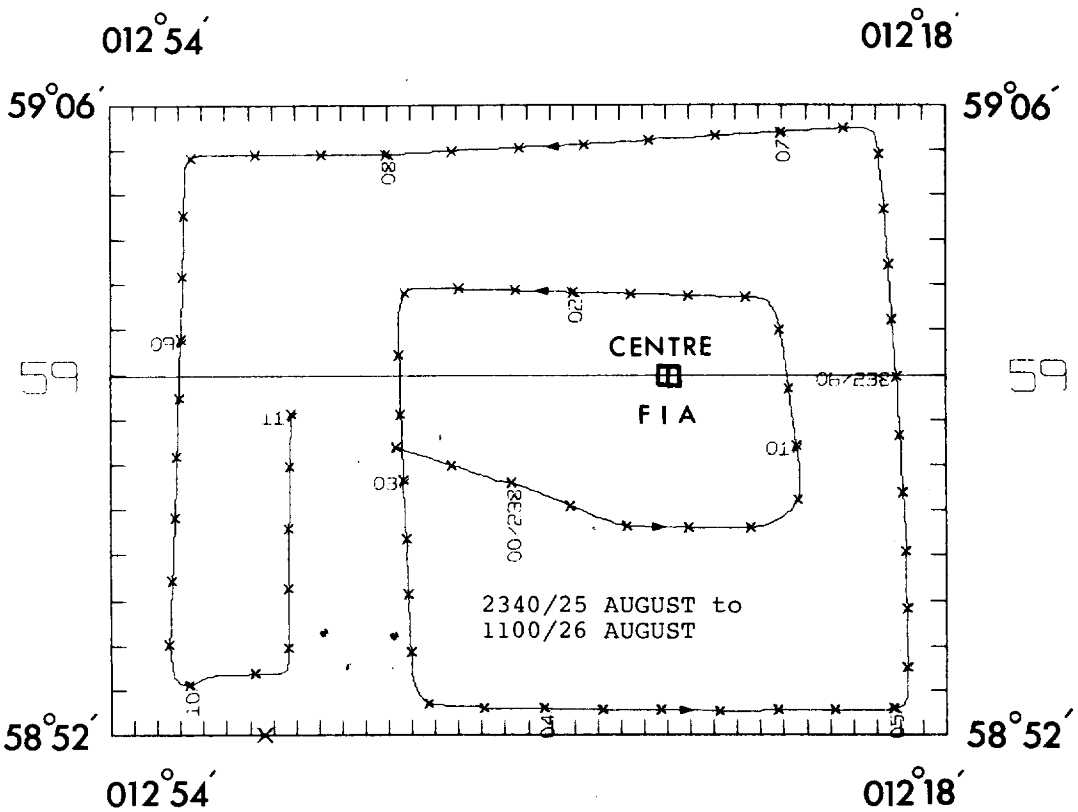


Fig. 6 Batfish survey round FIA

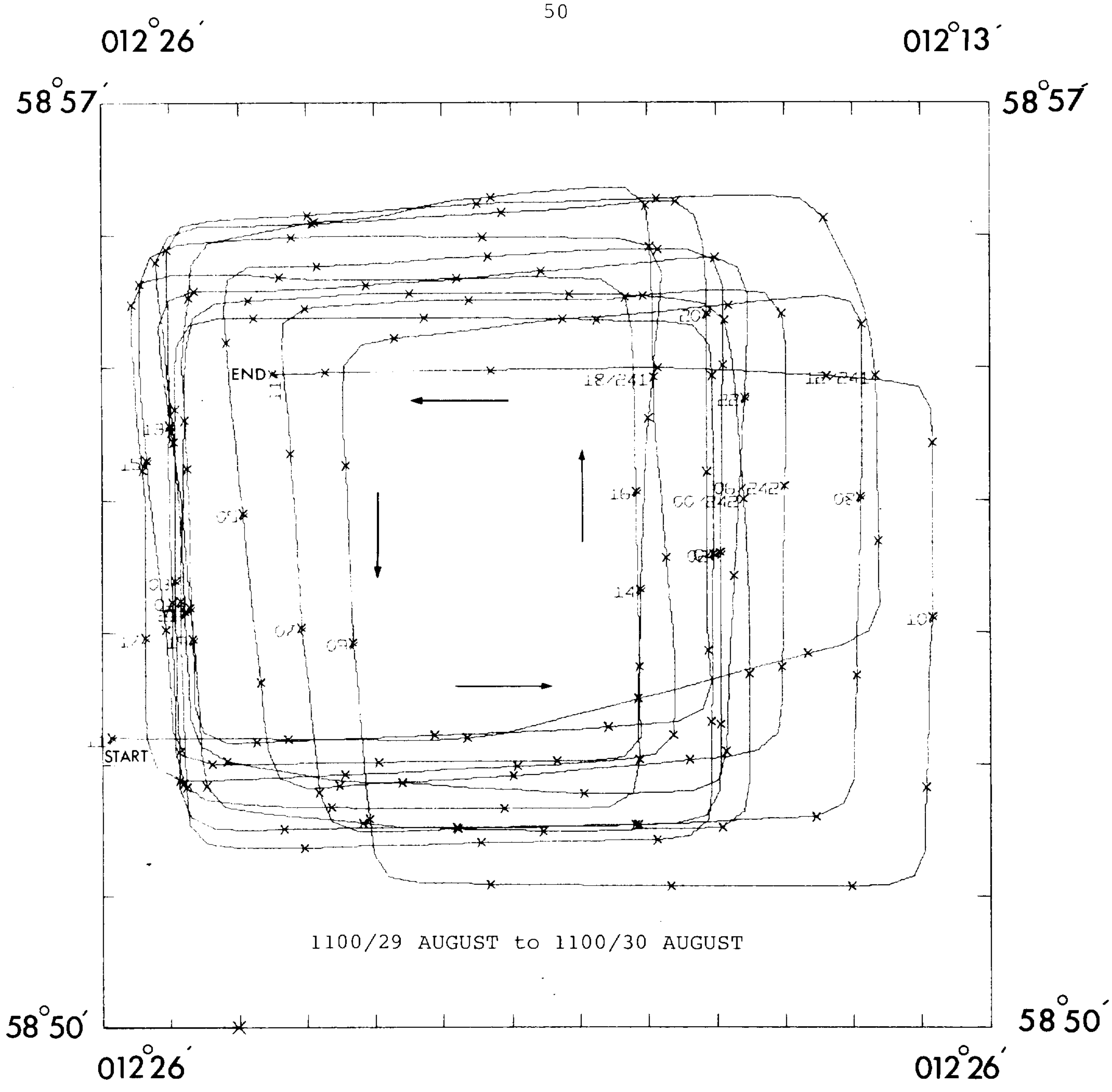


Fig. 7 Batfish survey round P2(262) during first multiship experiment.

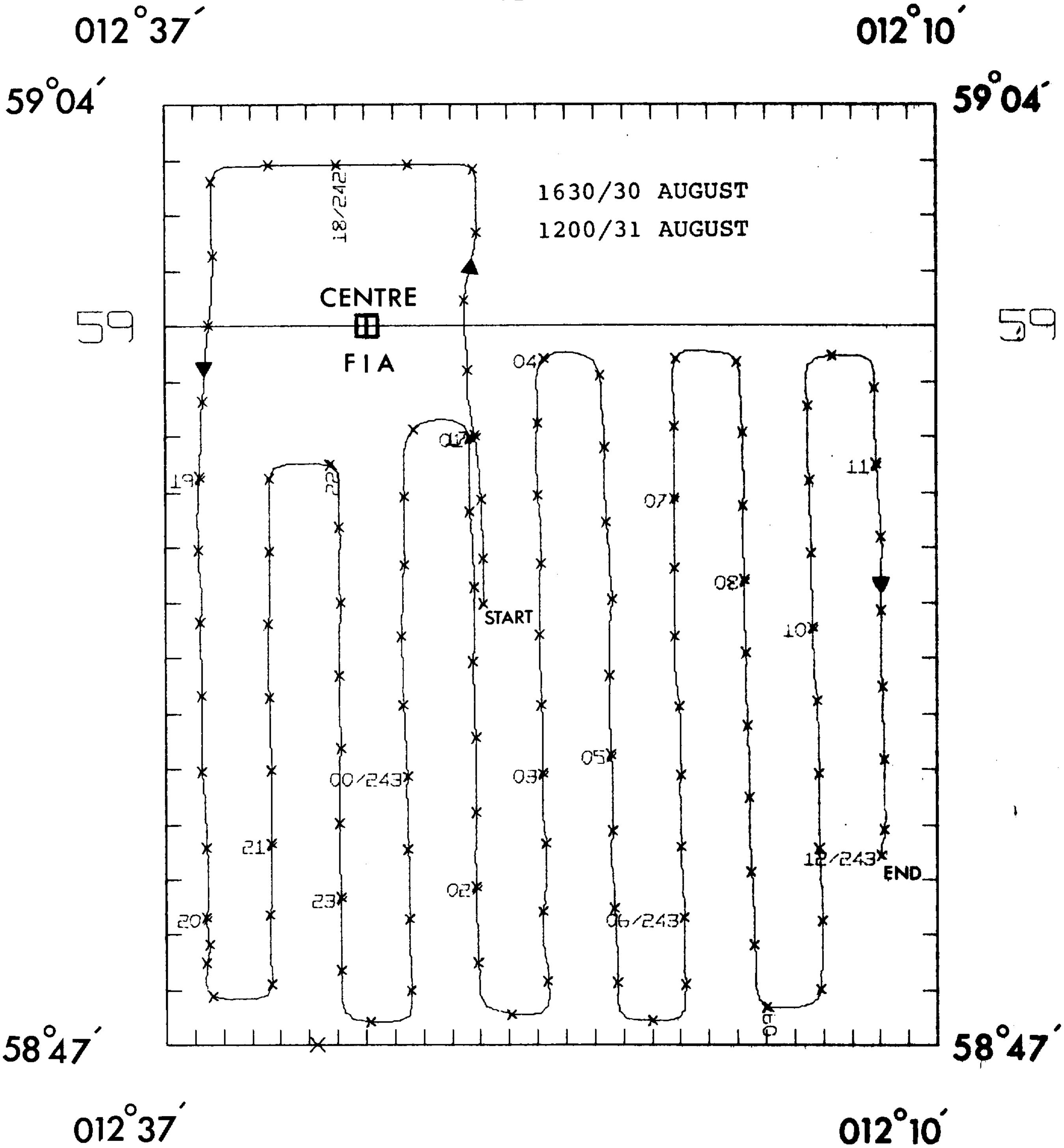


Fig. 8 - Batfish mapping survey.

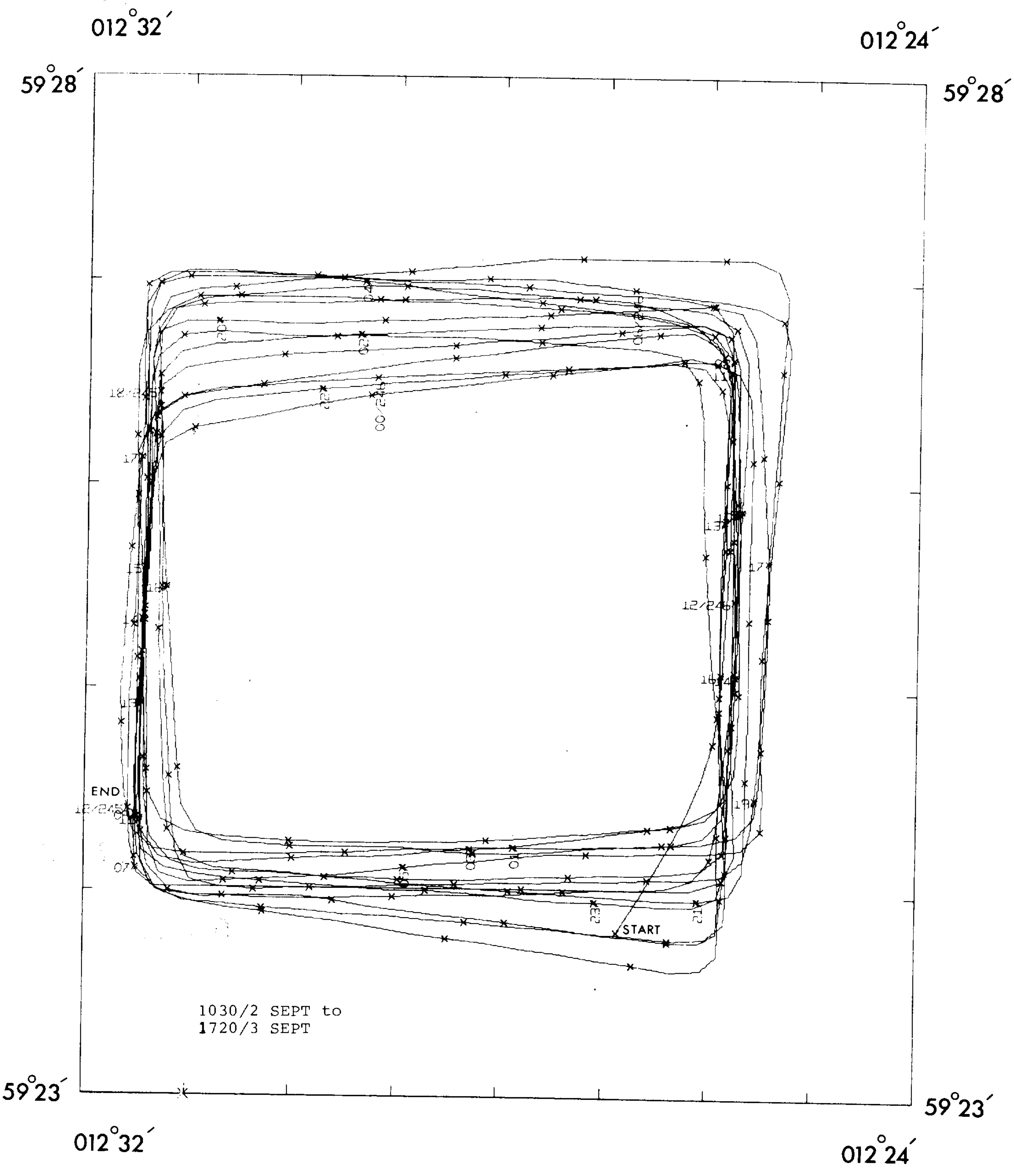


Fig. 9 -- Batfish survey round H2 during second multiship experiment.

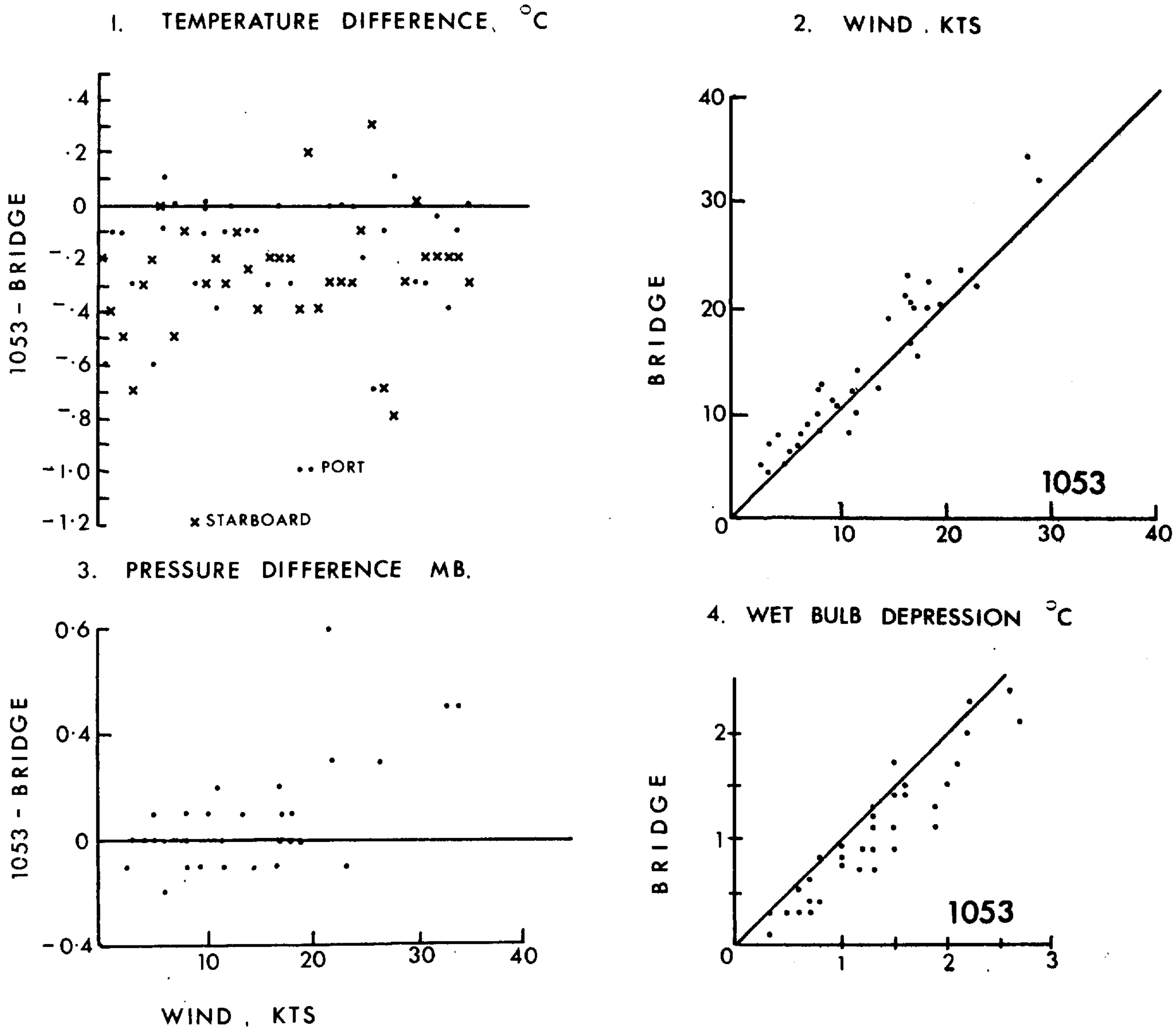


Fig. 10 Comparison of meteorological measurements from bridge and computer logged values (1053).

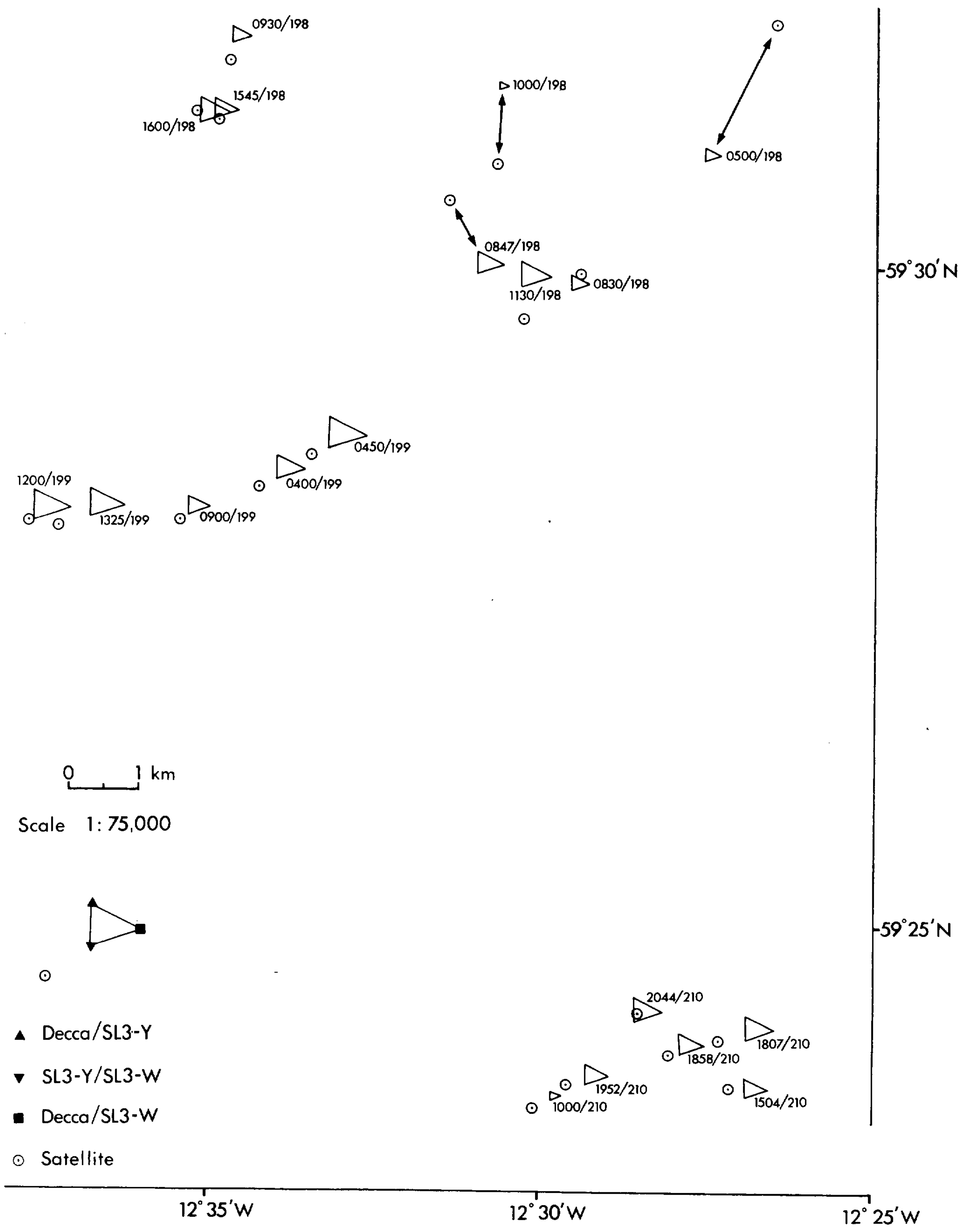


Fig. 11 Comparison of Loran, Loran/Decca, and satellite fixes.

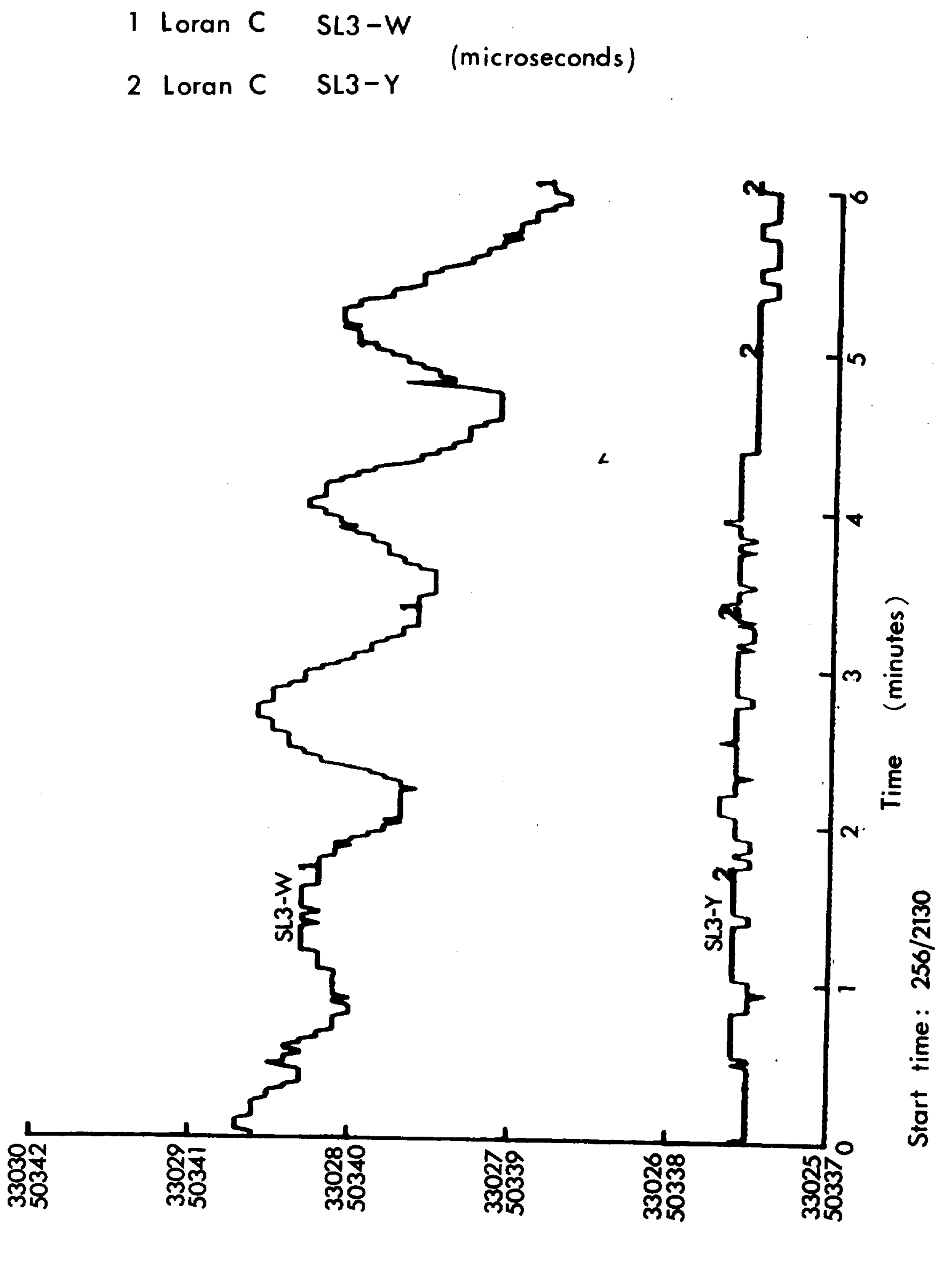


Fig. 12 Variation with time of the Loran SL3-W and SL3-Y raw readouts in microseconds.

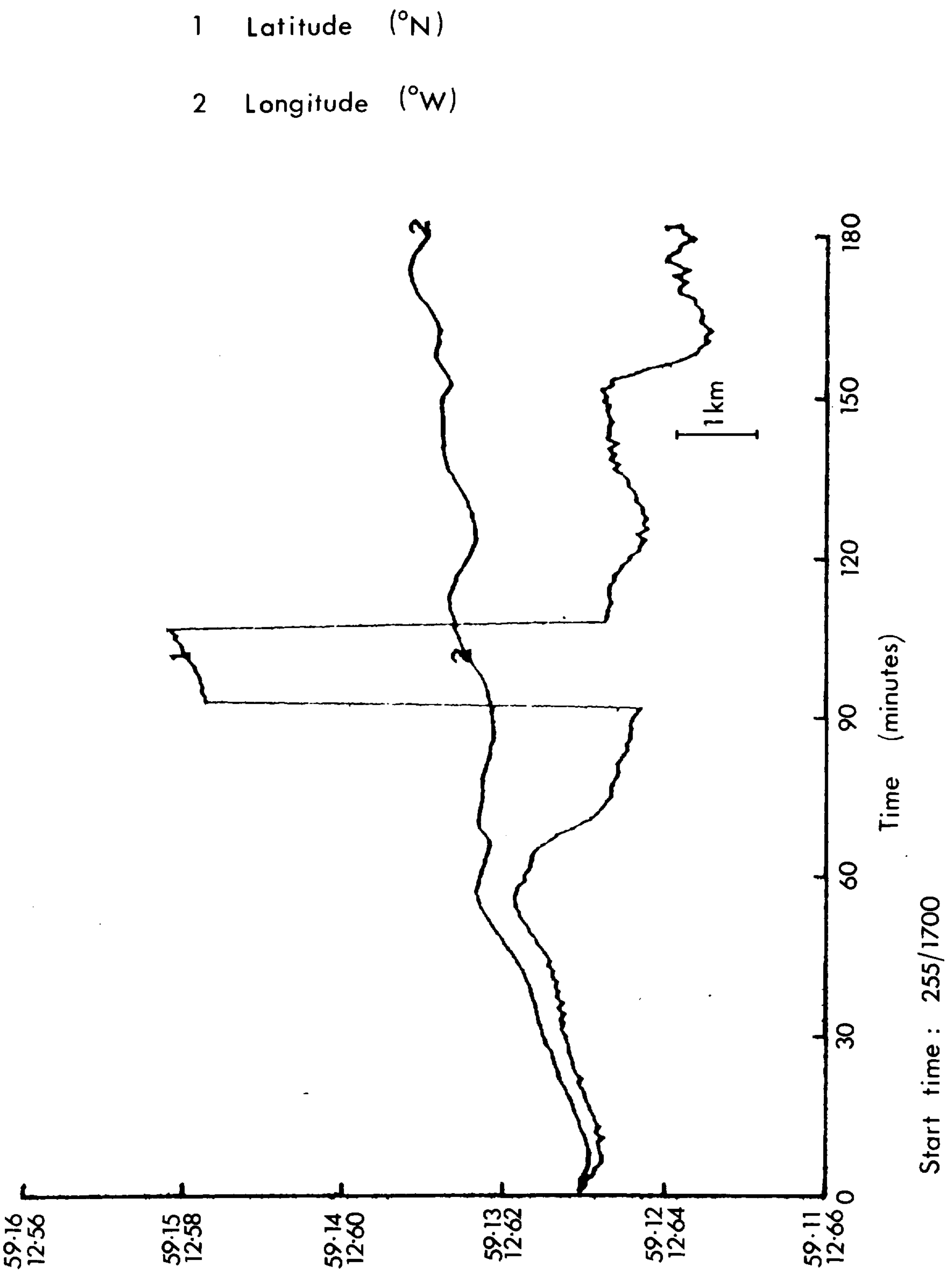


Fig. 13 Variation with time of latitude and longitude from the Loran SL3-W and SL3-Y one minute averages.

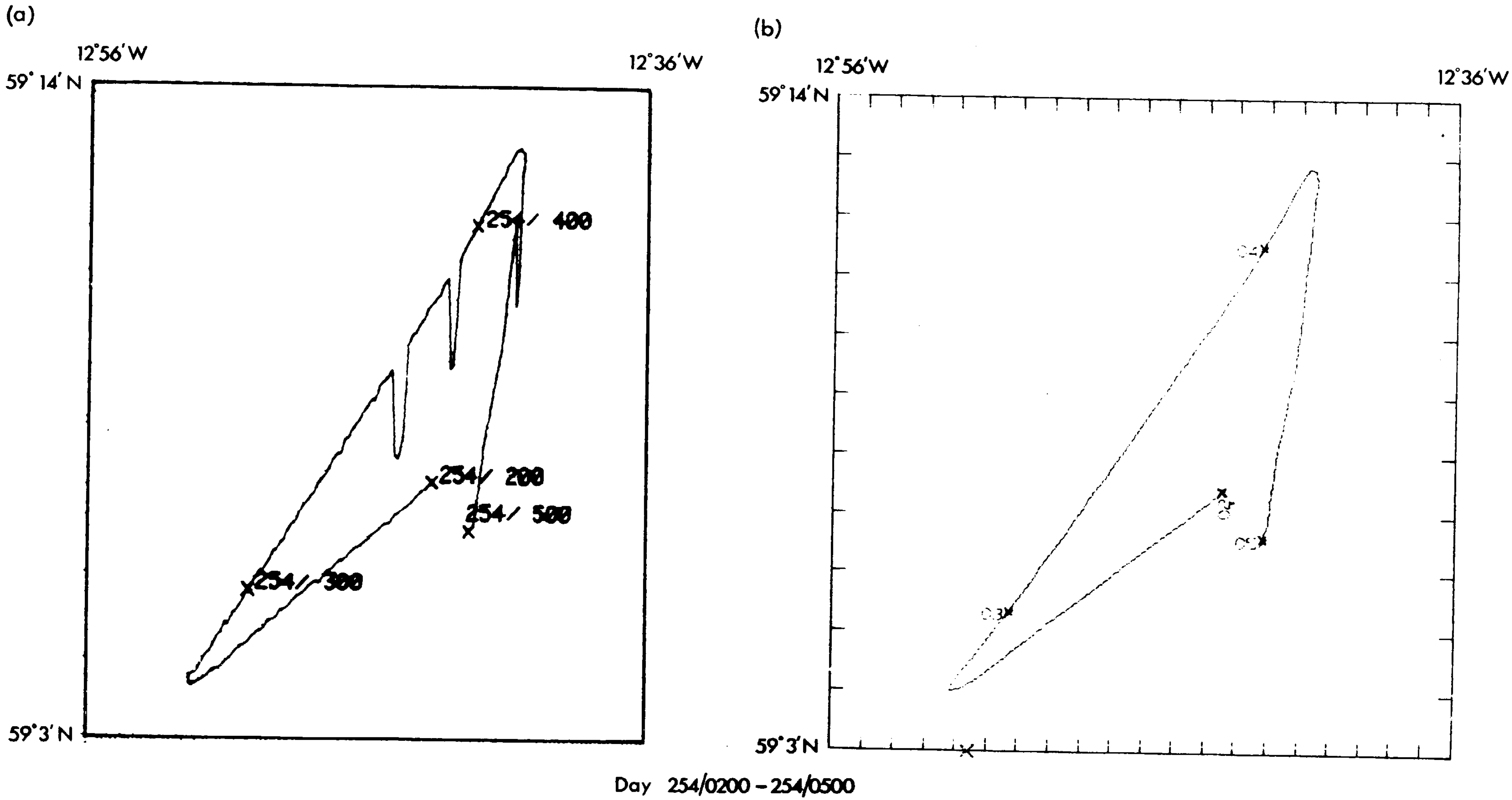


Fig. 14 (a) Loran track plot, (b) Corresponding track plot based on half hourly Loran fixes with interpolation by electromagnetic log and gyro.

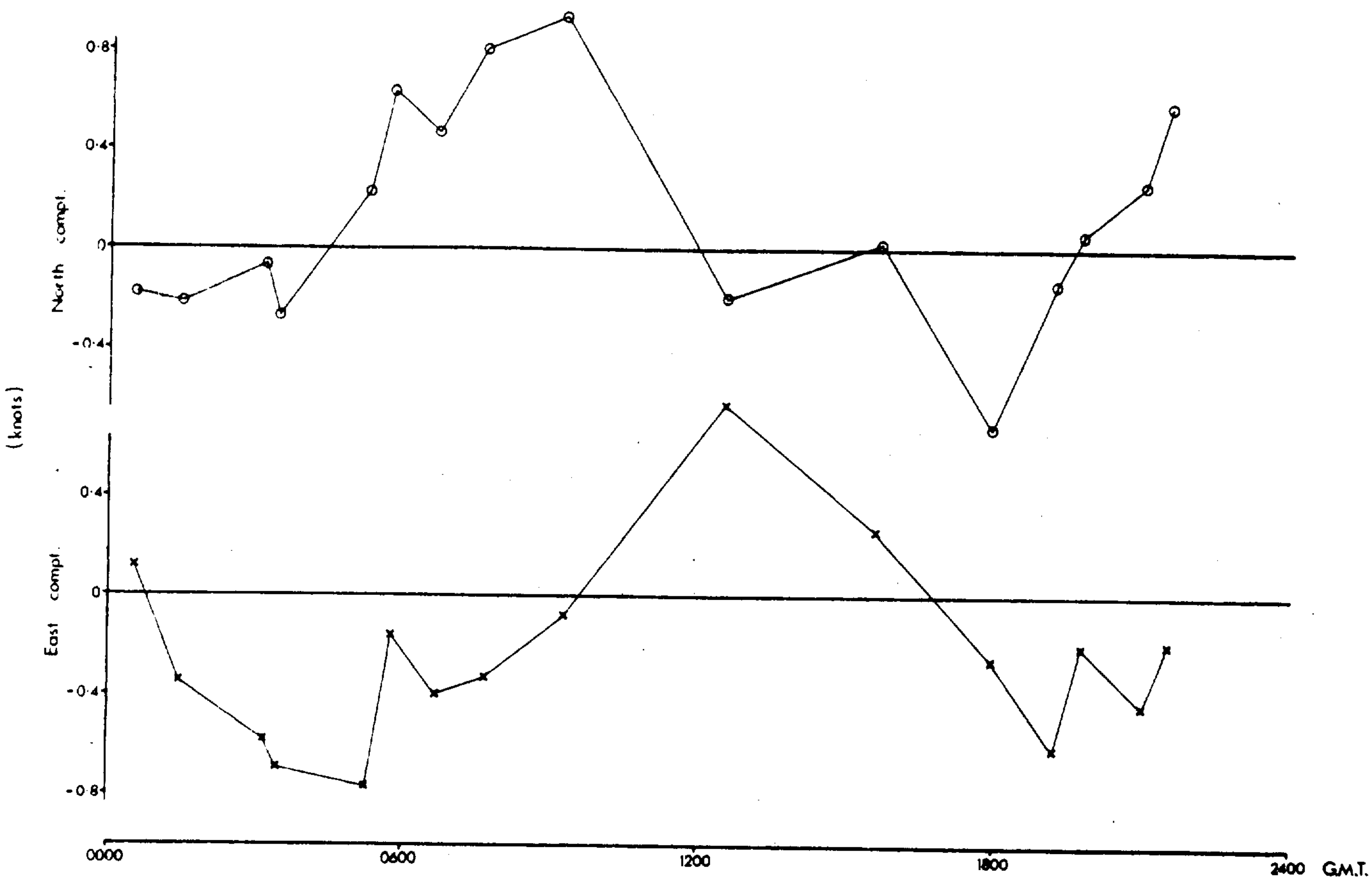


Fig. 15a Surface currents deduced (see text) from satellite fixes.

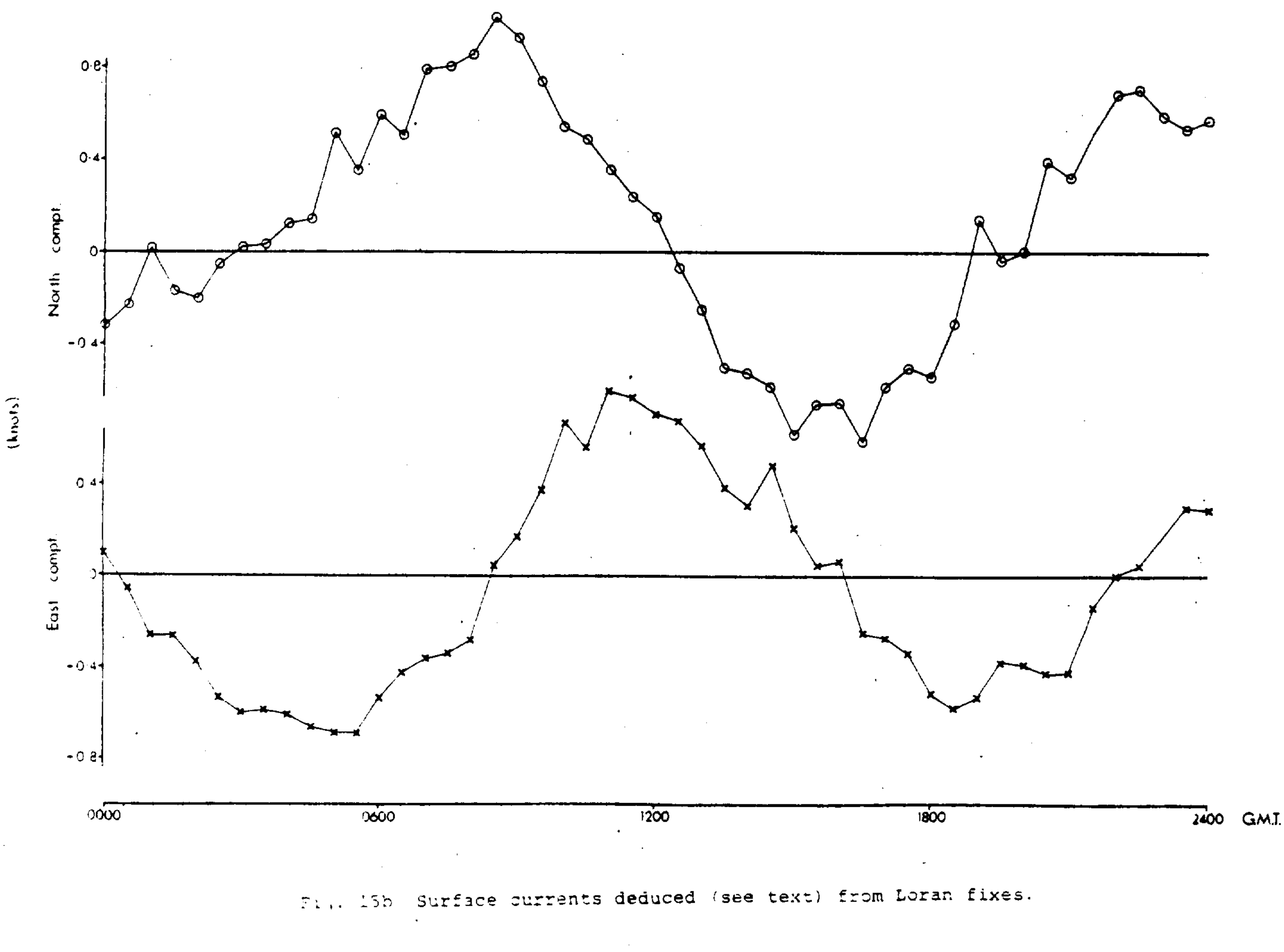


Fig. 15b Surface currents deduced (see text) from Loran fixes.

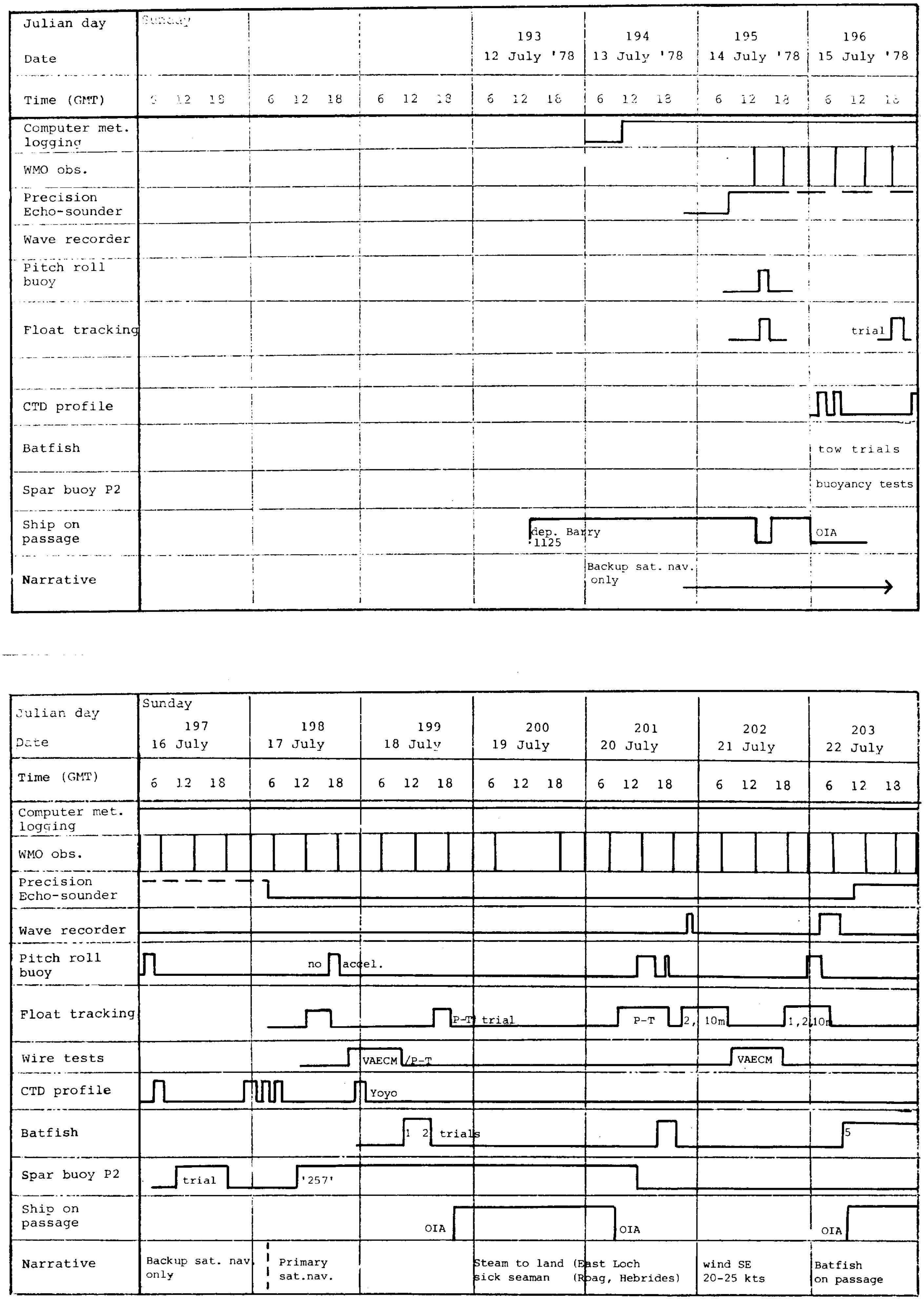


Fig. 16 R.R.S. Discovery Activity Diagram

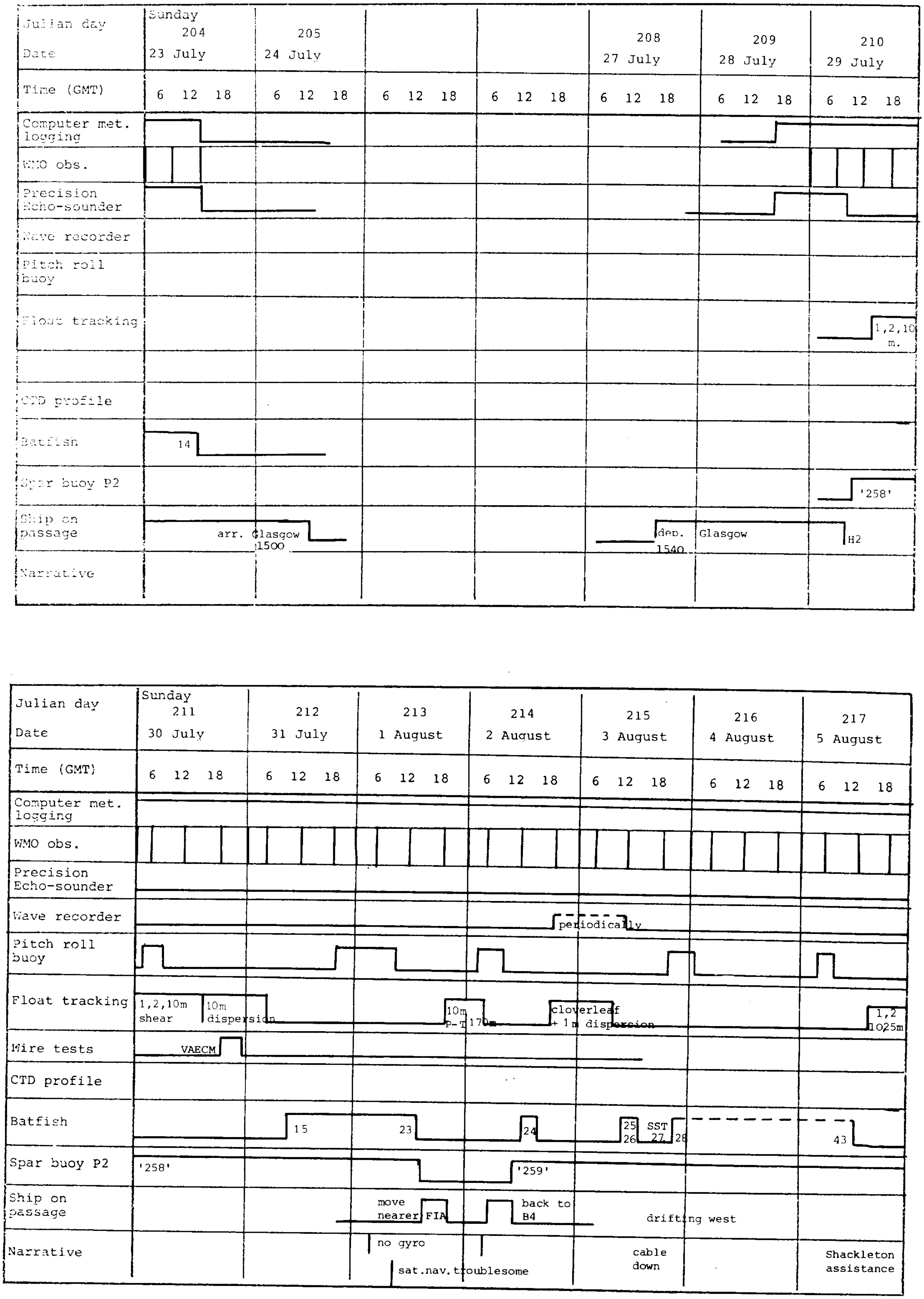


Fig. 16 R.R.S. Discovery Activity Diagram

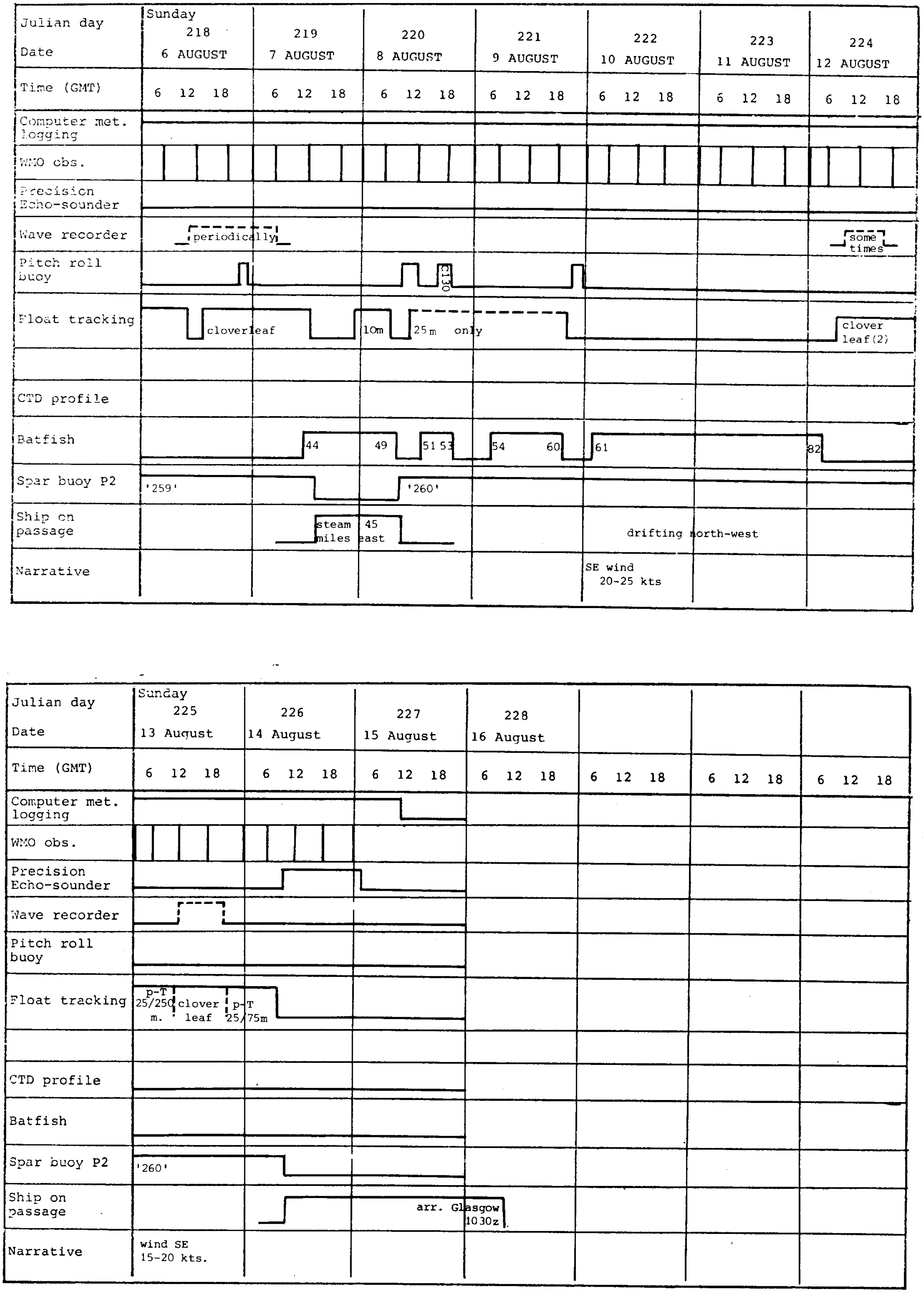


Fig. 16 R.R.S. *Discovery* Activity Diagram

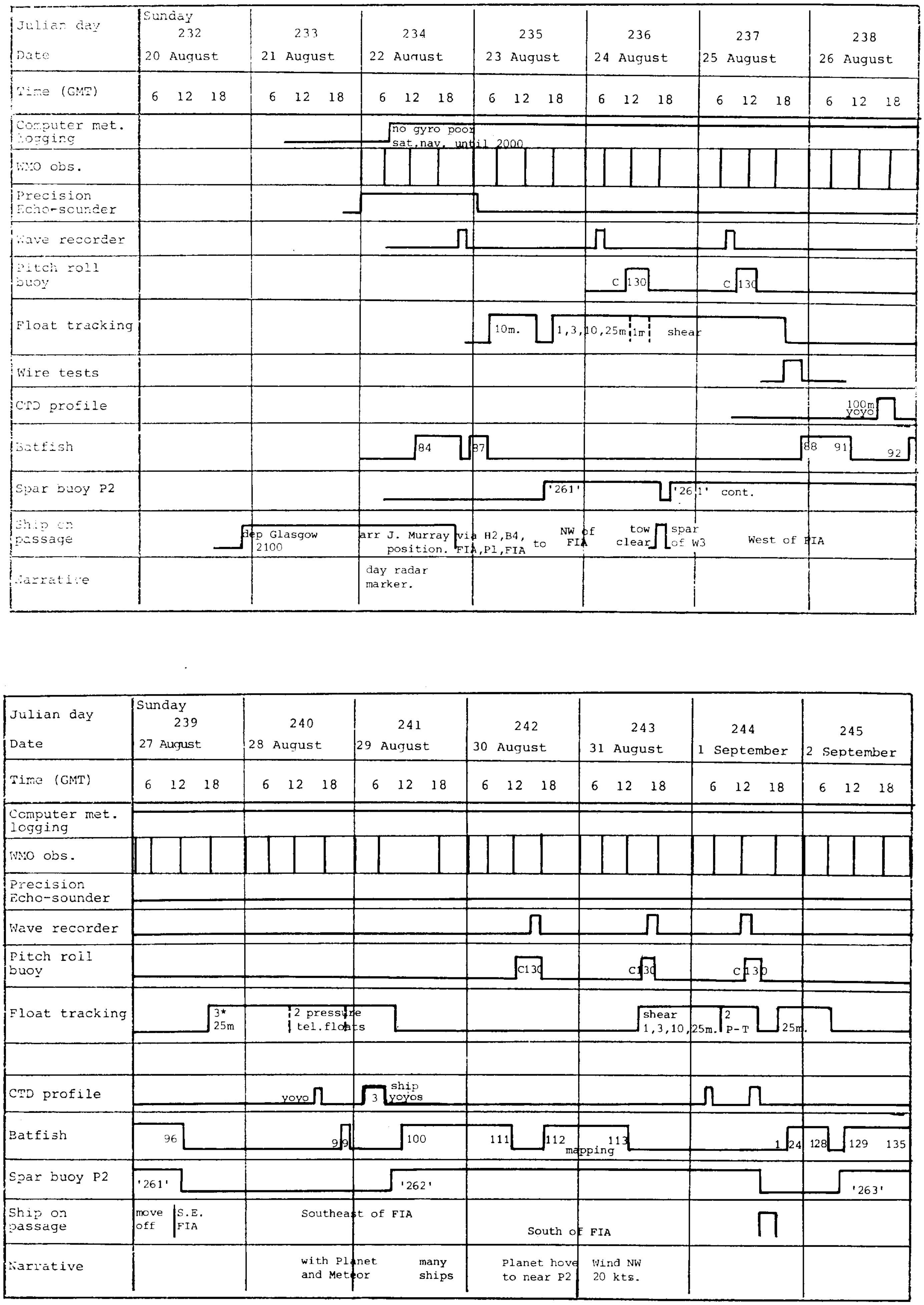


Fig. 16 R.R.S. Discovery Activity Diagram

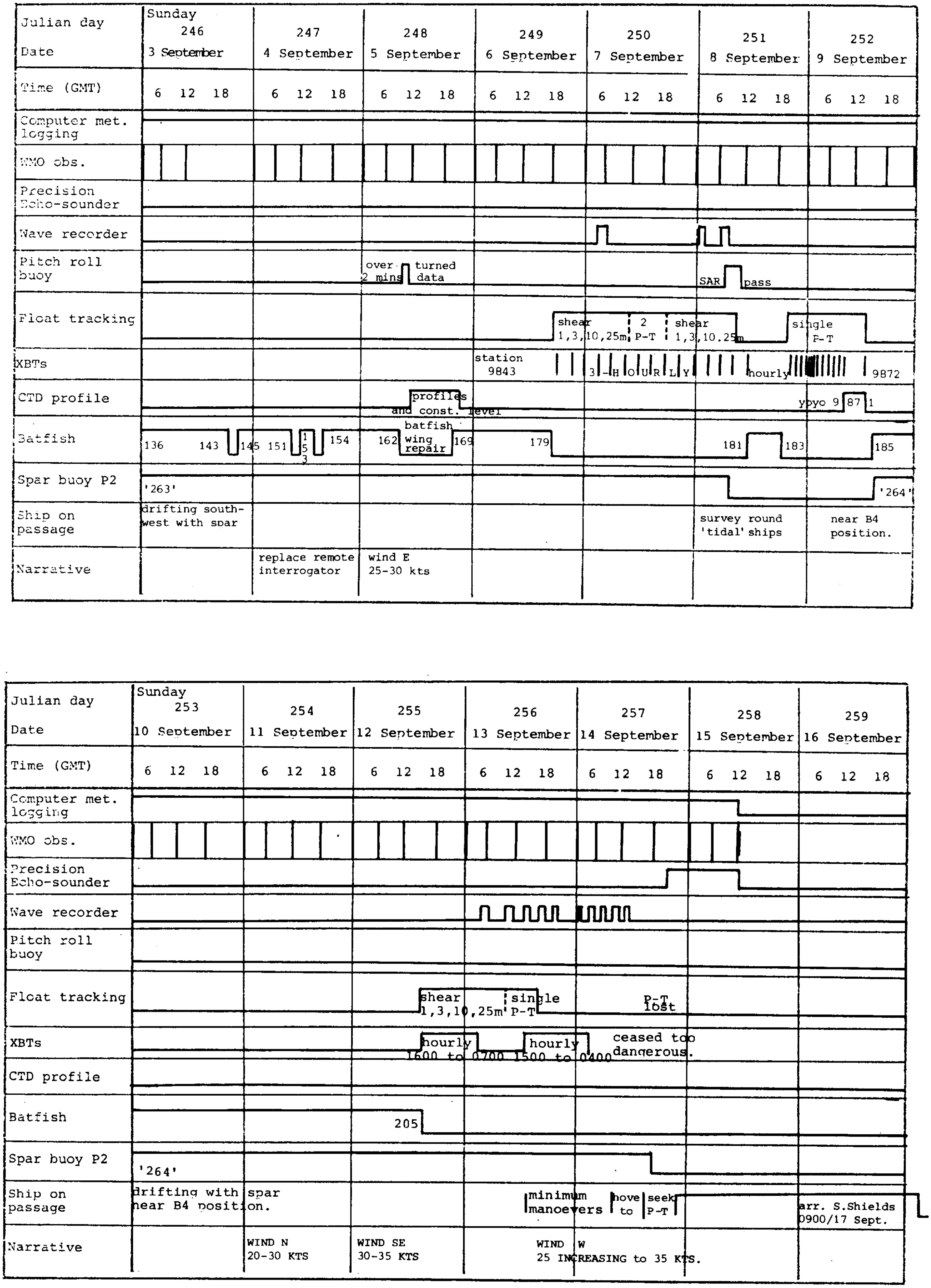


Fig. 16 R.R.S. Discovery Activity Diagram

Julian (year) Day and Date

Date	Day	Date	Day	Date	Day
July 12	193	July 19	200	July 26	207
13	194	20	201	27	208
14	195	21	202	28	209
15	196	22	203	29	210
16	197	23	204	30	211
17	198	24	205	31	212
18	199	25	206		
Aug. 1	213	Aug. 12	224	Aug. 23	235
2	214	13	225	24	236
3	215	14	226	25	237
4	216	15	227	26	238
5	217	16	228	27	239
6	218	17	229	28	240
7	219	18	230	29	241
8	220	19	231	30	242
9	221	20	232	31	243
10	222	21	233		
11	223	22	234		
Sept. 1	244	Sept. 7	250	Sept. 13	256
2	245	8	251	14	257
3	246	9	252	15	258
4	247	10	253	16	259
5	248	11	254	17	260
6	249	12	255		

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56	OCT - NOV 1973	4
57	NOV - DEC 1973	6
58	DEC 1973	4
59	FEB 1974	14
60	FEB - MAR 1974	8
61	MAR - MAY 1974	10
62	MAY - JUN 1974	11
63	JUN - JUL 1974	12
64	JUL - AUG 1974	13
65	AUG 1974	17
66	AUG - SEP 1974	20
68	NOV - DEC 1974	16
69	JAN - MAR 1975	51
73	JUL - AUG 1975	34
74/1+3		35
	SEP - OCT 1975	
74/2		33
75	OCT - NOV 1975	43
77	JUL - AUG 1976	46
78	SEP - OCT 1976	52
79	OCT - NOV 1976	54
82	MAR - MAY 1977	59
83	MAY - JUN 1977	61
84	JUN - JUL 1977	60
86	SEP 1977	57
87	OCT 1977	58
88	OCT - NOV 1977	65
89	NOV - DEC 1977	67
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91	MAR 1978	69
92	APR - MAY 1978	70

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