II. POSITIONING BY NNSS AND ESTIMATION OF A BOTTOM-HITTING POINT OF A FREEFALL GRAB IN THE GH79-1 AREA

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Positioning

NNSS is only a real way for positioning and navigational purposes in the central Pacific including the survey area at the present time. Some technical problems concerning NNSS have already been discussed by CHUJO and MURAKAMI (1975), and the recalculation procedure of ship's positions and its effectiveness were reported by ISHIHARA and ISHIBASHI (1977) and ISHIHARA (1977). JOSHIMA and ONODERA (1979) showed the example of ship's positions obtained by LORAN, OMEGA, and NNSS, and indicated that the positioning by NNSS was the most accurate among them.

Estimated error of a recalculated position is given by

$$R = 0.1 + \alpha \times t\,(\text{n.m.}),$$

where t is the time from the closest good satellite fix, and the coefficient α has a value of about 0.2 n.m./hr in average (ISHIHARA and ISHIBASHI, 1977; JOSHIMA and ONODERA, 1979). The error depends on t, i.e., the occurrence frequency of good satellite fixes. The five satellites network of NNSS serves now in the world, but the distribution of the satellites is not equi-spaced, so that the hourly occurrence frequency depends on both sidereal time and location of a ship.

Figure II-1 shows the occurrence frequency of satellite fixes vs. universal time in the

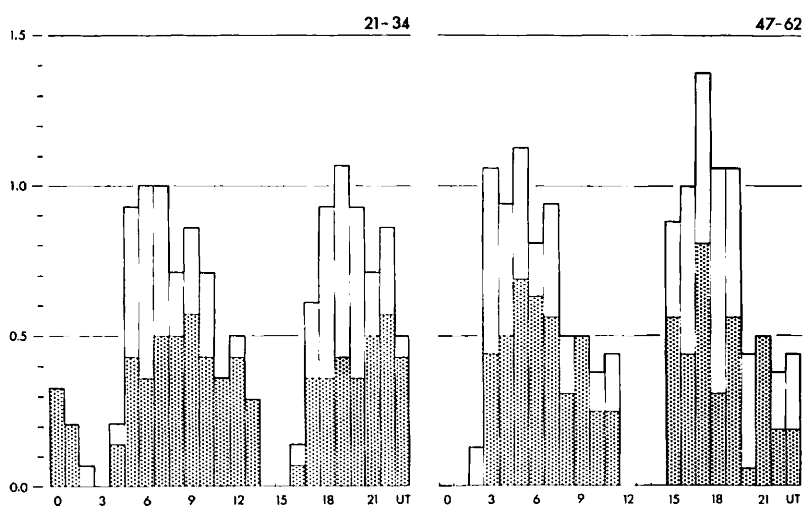


Fig. II-1 Hourly occurrence frequency of the good satellite fixes. The dotted histogram is of the automatic fixes by NNSS and the other is of the manual fixes.

earlier half (day 21 to 34) and the later half (day 47 to 62) of the cruise in the survey area, where the local time is 11 hours later than UT. As shown in Fig. II-1, satellite fixes occurred most often between 5 UT and 12 UT, and 17 UT and 23 UT in the earlier half, and between 3 UT and 11 UT, and 15 UT and 23 UT in the later half. Slight difference in hours between the two halves is caused by the sidereal time dependence of the hourly occurrence frequency (the effect of the revolution of the earth). It is concluded that the recalculation error in those hours is statistically less than 0.3 n.m. in the worst case.

The estimated errors by the recalculation of the stationary positions are summarized in Table II-1.

Estimation of a bottom-hitting point of a freefall grab

Sampling operations by using two to four freefall grabs were carried out at nearly all the stations. Sampling positions of freefall grabs have been determined as the throw-in positions of the grabs (see Table I-5 in MORITANI, 1979). In our cruise, we also concluded that the sampling positions of grabs can be regarded as throw-in positions from considerations of the coming up and pickup positions of grabs.

The examples of the throw-in and pickup positions of freefall grabs at Sts. 1465 and 1473 are illustrated in Fig. II-2. As shown in this figure, relative positions of the grabs at the pickup time do not so change one another as compared with those at the throw-in time, while there is some distance between the throw-in and pickup points. Those imply that grabs were floated by certain regular flows not by random ones. The flows may be divided into two parts, one of which is a surface current and the other is subsurface currents. If we observe a coming up position of a grab, we can know the horizontal motion of a grab by the subsurface currents and that by the surface current, and further verify the bottom-hitting position of a freefall grab.

In order to know a coming up position of a grab, the distance and the direction from the ship to the grab at the coming up time were observed at each station in the later half of the survey, and the position was calculated.

In the later half of the survey, two freefall grabs were thrown in at an interval of five minutes. The throw-in, coming up, and pickup positions of the freefall grabs are shown in Fig. II-3, where the sampling by one of grabs at Sts. 1482 and 1481A3 were failed, and only one grab was operated at St. 1486. It is noticed that almost all the couple of the grabs at each station moved in nearly same pattern. At St. 1481A a freefall vanetester was thrown in together with two grabs, but it did not reach the ocean bottom. The fault of the ventester operation is indicated by its flow pattern shown by dushed line in the figure. The freefall grabs 1 and 2 moved toward the north-northeast at first and then floated northwestward, but the vanetester moved only northwestward. This means that the motion of the vanetester was influenced only by the surface current whereas the grabs were forced north-northeastward by some subsurface currents before coming up.

A drift pattern made by the line from the throw-in point to the pickup point through the coming up point is not a straight line except for a few cases. This suggests that there are subsurface currents of which directions differ from that of a surface current, as discussed above.

Now assume that subsurface currents are invariant with time, and do not have a

Table II-1 Results of recalculation of observed positions.

St. no.	Observ. no.	Day	Time (UT)	Recalculated position Lat. (N)	Long. (W)	Error n.m.	Fix time
1448	G(B)915	21	1850	12–58.41	178–01.81	0.15	1836, 1916
	FG115-1		1702	58.94	01.81	0.41	1836
	115C-1		1705	58.88	01.85	0.40	
	115-2		1710	58.75	01.93	0.39	
	115C-2		1712	58.68	01.96	0.38	
1449	G(B)916A	22	0438	12–59.58	176–59.61	0.43	0228, 0617
	FG116-1		0308	59.73	177–00.12	0.23	0228
	116C-1		0309	59.75	00.08	0.24	
	116-2		0315	59.80	176–59.96	0.26	
	116C-2		0317	59.83	59.89	0.26	
1450	G(B)917	22	1842	13–01.09	176–01.08	0.15	1826, 1926
	FG117-1		1657	00.62	01.35	0.40	1826
	117C-1		1700	00.71	01.31	0.39	
	117-2		1706	00.83	01.29	0.37	
	117C-2		1709	00.89	01.23	0.36	
1451	G(B)918	23	0430	13–01.63	174–59.13	0.74	0117, 0916
	FG118-1		0230	00.82	59.61	0.34	0117
	118C-1		0232	00.86	59.59	0.35	
	118-2		0237	00.98	59.50	0.37	
	118C-2		0239	01.02	59.48	0.37	
1452	G(B)919	23	1837	13–02.68	174–00.10	0.12	1832
	FG119-1		1655	01.86	00.34	0.42	1832
	119C-1		1658	01.93	00.31	0.41	
	119-2		1702	02.08	00.23	0.40	
	119C-2		1705	02.17	00.19	0.39	
1453	G(B)920	24	0442	13–01.60	172–58.59	0.40	0011, 0612
	FG120-1		0300	00.81	58.94	0.66	0011
	120C-1		0302	00.86	58.96	0.68	
	120-2		0306	01.00	58.87	0.68	
	120C-2		0308	01.06	58.83	0.69	
1454	G(B)921	24	1834	12–00.03	173–00.26	0.12	1828
	FG121-1		1652	11–59.10	00.35	0.42	1828
	121C-1		1655	59.19	00.32	0.41	
	121-2		1700	59.41	00.22	0.39	
	121C-2		1703	59.47	00.20	0.38	
1455	G(B)922	25	0421	10–59.18	173–00.07	0.41	0055, 0555
	FG122-1		0242	58.45	172–59.97	0.46	0055
	122C-1		0243	58.50	59.93	0.46	
	122-2		0249	58.67	59.79	0.48	
	122C-2		0251	58.70	59.74	0.49	
1456	G(B)923	23	2208	11–01.63	171–59.48	0.21	2136, 2256

Table II-1 (Continued)

St. no.	Observ. no.	Day	Time (UT)	Recalculated position Lat. (N)	Long. (W)	Error n.m.	Fix time
1456	FG123-1	23	2029	11–00.97	171–59.54	0.32	2136
	123C-1		2033	01.09	59.48	0.31	
	123-2		2038	01.23	59.39	0.29	
	123C-2		2040	01.30	59.35	0.29	
1457	G(B)924	26	0759	12–01.78	172–00.45	0.12	0754
	FG124-1		0619	00.23	00.13	0.14	0607
	124C-1		0621	00.22	00.22	0.15	
	124-2		0626	00.13	00.13	0.16	
	124C-2		0628	00.09	00.09	0.16	0647
1458	G(B)925	26	1840	13–00.21	172–00.28	0.13	1830
	FG125-1		1651	00.03	00.58	0.24	1732
	125C-1		1654	00.09	00.55	0.23	
	125-2		1659	00.25	00.46	0.21	
	125C-2		1702	00.34	00.43	0.20	
1459	G(B)926	27	0448	12–57.47	170–59.75	0.19	0514
	FG126-1		0303	57.30	171–00.17	0.54	0514
	126C-1		0306	57.33	00.14	0.53	
	126-2		0311	57.45	00.02	0.51	
	126C-2		0313	57.49	170–59.98	0.50	
1460	G(B)927	27	1642	11–58.91	171–03.20	0.44	1824
	FG127-1		1508	58.86	02.97	0.75	1824
	127C-1		1510	58.85	03.09	0.75	
	127-2		1515	58.84	03.40	0.73	
	127C-2		1517	58.83	03.51	0.72	
1461	G(B)928	28	0412	10–59.76	171–04.52	0.47	0602
	FG128-1		0237	59.48	03.95	0.43	0059
	128C-1		0239	59.52	04.04	0.43	
	128-2		0244	59.54	04.35	0.45	
	128C-2		0246	59.53	04.47	0.46	
1462	G(B)929	29	0114	11–24.81	170–00.17	0.37	2352, 0508
	FG129-1	28	2346	24.21	169–59.49	0.12	2352
	129C-1		2348	24.29	59.46	0.11	
	129-2		2353	24.40	59.42	0.10	
	129C-2		2355	24.46	59.39	0.11	
1463	G(B)930	29	0812	12–01.02	170–06.22	0.15	0749, 0826
	FG130-1		0632	00.43	169–59.88	0.17	0600, 0654
	130C-1		0633	00.48	59.84	0.17	
	130-2		0638	00.65	59.72	0.15	
	130C-2		0640	00.70	59.69	0.15	
1464	G(B)931	29	1834	13–00.77	170–01.09	0.27	1744, 1928
	FG131-1		1651	12–59.95	00.79	0.28	1744

Table II-1 (Continued)

St. no.	Observ. no.	Day	Time	Recalculated position		Error	Fix time
		(UT)		Lat. (N)	Long. (W)	n.m.	
1464	FG131C-1	29	1654	13–00.03	170–00.79	0.27	
	131-2		1659	00.17	00.73	0.25	
	131C-2		1701	00.23	00.69	0.24	
1465	G(B)932	30	0415	13–00.31	169–00.21	0.44	0558
	FG132-1		0227	12–59.92	168–59.54	0.49	0031
	132C-1		0228	59.94	59.55	0.49	
	132-2		0233	13–00.03	59.37	0.51	
	132C-2		0235	00.05	59.32	0.51	
1466	G(B)933	30	1932	12–00.55	169–00.25	0.17	1910, 2036
	FG133-1		1755	00.07	00.05	0.20	1724, 1835
	133C-1		1758	00.10	168–59.98	0.21	
	133-2		1803	00.24	59.42	0.21	
	133C-2		1805	00.28	59.77	0.20	
1467	G(B)934	31	0421	11–09.92	169–00.06	0.24	0504
	FG134-1		0249	09.46	00.33	0.43	0109
	134C-1		0251	09.50	00.27	0.44	
	134-2		0256	09.59	00.10	0.46	
	134C-2		0258	09.62	00.06	0.46	
1468	G(B)935	31	1832	11–00.17	167–58.87	0.16	1814, 1932
	FG135-1		1652	00.15	59.24	0.28	1746
	135C-1		1654	00.17	59.14	0.27	
	135-2		1659	00.21	58.95	0.26	
	135C-2		1702	00.23	58.88	0.25	
1469	G(B)936	32	0358	12–00.77	168–00.87	0.35	0002, 0512
	FG136-1		0219	00.32	167–59.52	0.56	0002
	136C-1		0221	00.36	59.49	0.56	
	136-2		0226	00.46	59.46	0.58	
	136C-2		0228	00.49	59.45	0.59	
1470	G(B)937	32	2100	12–59.74	168–00.27	0.15	2116
	FG137-1		1918	59.60	167–59.97	0.13	1909, 1930
	137C-1		1920	59.64	59.95	0.13	
	137-2		1925	59.73	59.87	0.12	
	137C-2		1927	59.77	59.84	0.11	
1471	G(B)938	33	0652	13–02.32	167–01.58	0.12	0645
	FG138-1		0510	01.41	00.48	0.12	0503
	138C-1		0512	01.47	00.39	0.13	
	138-2		0516	01.62	00.18	0.14	
	138C-2		0518	01.66	00.15	0.15	
1472	G(B)939	33	1736	12–00.87	166–58.65	0.14	1748
	FG139-1		1552	00.50	58.79	0.20	1623
	139C-1		1555	00.57	58.72	0.19	

Table II-1 (Continued)

St. no.	Observ. no.	Day	Time (UT)	Recalculated position Lat. (N)	Long. (W)	Error n.m.	Fix time
1472	FG139-2	33	1600	12–00.69	166–58.63	0.18	
	139C-2		1602	00.75	58.57	0.17	
1473	G(B)940	34	0104	11–20.17	167–00.93	0.94	2046, 0515
	FG140-1		2331	19.67	00.37	0.65	2046
	140C-1		2333	19.71	00.32	0.66	
	140-2		2338	19.80	00.20	0.67	
	140C-2		2340	19.84	00.15	0.68	
1474	G(B)941	47	1843	10–10.30	167–20.43	0.18	1812, 1908
	FG141C-1		1656	10.06	20.30	0.21	1624, 1742
	141C-2		1701	10.27	20.19	0.22	
1475	G(B)942	47	2230	10–00.10	167–18.67	0.21	2158, 2342
	FG142C-1		2059	09–59.89	19.12	0.30	2158
	142C-2		2104	59.90	18.92	0.28	
1476	G(B)943	48	0257	09–49.96	167–17.68	0.23	2342, 0336
	FG143C-1		0057	49.71	18.45	0.35	2342
	143C-2		0102	49.73	18.28	0.37	
1477	G(B)944	48	1836	09–51.02	167–33.51	0.15	1821, 1854
	FG144C-1		1702	51.52	33.28	0.13	1652, 1718
	144C-2		1707	51.29	33.45	0.14	
1478	G(B′)945	48	2308	10–00.29	167–30.35	0.71	2006
	FG145C-1		2104	00.10	30.03	0.29	2006
	145C-2		2109	00.16	29.88	0.31	
1479	G(B)946	49	0320	10–10.45	167–30.19	0.31	2006, 0423
	FG146C-1		0146	10.30	30.39	0.62	0423
	146C-2		0151	10.35	30.19	0.61	
1480	G(B)947	49	1829	10–10.51	167–50.33	0.18	1805, 1919
	FG147C-1		1654	09.94	50.67	0.19	1626, 1736
	147C-2		1700	10.26	50.39	0.21	
1481	G(B′C)948	49	2250	10–01.36	167–48.83	0.19	2130, 2316
	FG148C-1		2051	00.72	49.30	0.23	2130
	148C-2		2055	00.85	49.29	0.22	
1482	G(B)949	50	0259	09–49.85	167–50.02	0.21	0332
	FG149C-1		0131	49.41	50.46	0.50	0332
	149C-2		0137	49.52	50.–8	0.48	
1483	G(B)950	50	1834	09–49.64	167–38.99	0.12	1828
	FG150C-1		1705	49.60	39.77	0.17	1644
	150C-2		1710	49.79	39.71	0.19	

Table II-1 (Continued)

St. no.	Observ. no.	Day	Time (UT)	Recalculated position Lat. (N)	Long. (W)	Error n.m.	Fix time
1484	G(B′C)951	50	2303	09–59.48	167–39.60	0.28	2206, 2358
	FG151C-1		2105	59.93	40.02	0.26	2016
	151C-2		2110	10–00.09	40.03	0.28	
1485	G(B)952	51	0304	10–09.34	167–40.87	0.35	2358, 0420
	FG152C-1		0136	09.47	40.76	0.43	2358
	152C-2		0141	09.61	40.80	0.44	
1481A	P137	51	1850	10–00.72	167–49.70	0.22	1815
	FG153C-1		1700	00.93	48.94	0.20	1630, 1734
	153C-2		1704	00.71	48.92	0.21	
	153C-3		2158	01.41	48.69	0.25	2102, 2244
	153C-4		2203	01.27	48.56	0.24	
	D314	52	0044	00.84	50.02	0.50	2244, 0326
1481A1	FG154C-1	52	1744	09–59.88	167–49.73	0.17	1724, 1915
	154C-2		1754	59.85	48.76	0.20	
	154C-3		1803	59.82	47.79	0.23	
	154C-4		1813	59.78	46.80	0.26	
	154C-5		1823	59.76	45.81	0.27	
	154C-6		1833	59.73	44.82	0.24	
	154C-7		1843	59.71	43.84	0.21	
	154C-8		1853	59.68	42.86	0.17	
	154C-9		1903	59.64	41.89	0.14	
	154C-10		1914	59.61	40.90	0.10	
1484A1	FG155C-1	52	2334	09–59.90	167–40.08	0.13	2324
	155C-2		2343	59.83	39.11	0.16	
	155C-3		2352	59.80	38.13	0.19	
	155C-4	53	0002	59.73	37.17	0.23	
	155C-5		0013	59.69	36.21	0.26	
	155C-6		0022	59.64	35.23	0.29	
	155C-7		0032	59.59	34.26	0.33	
	155C-8		0041	59.55	33.28	0.36	
	155C-9		0051	59.50	32.32	0.39	
1481A2	FG156C-1	53	1647	09–59.58	167–47.60	0.14	1634
	156C-2		1649	59.57	47.49	0.15	
	C15		1846	59.43	48.04	0.18	1821, 1935, 2013
	FG156C-3		2145	59.36	46.88	0.41	2013
	P138		2312	59.21	47.38	0.70	
1486	D315	54	0556	10–33.19	168–00.11	0.14	0545
	FG157C		0427	34.50	00.15	0.19	0400
1452A	FG158C-1	58	0459	12–59.23	174–00.13	0.10	0458
	158C-2		0505	58.99	00.18	0.12	
	P139		0633	59.11	00.61	0.17	0612

Table II-1 (Continued)

St. no.	Observ. no.	Day	Time (UT)	Recalculated position Lat. (N)	Long. (W)	Error n.m.	Fix time
1487	P140	58	1800	11–59.29	174–00.80	0.11	1756
	FG159C-1		1624	59.40	00.58	0.10	1624
	159C-2		1629	59.58	00.56	0.12	
1488	P141	59	0247	10–58.74	174–00.91	0.35	2343
	FG160C-1		0115	59.38	00.25	0.41	2343
	160C-2		0121	58.62	00.28	0.43	
1489	G(B)953	60	2125	11–59.78	174–59.37	0.42	1949, 2312
	FG161C-1		1952	59.68	59.48	0.11	1949
	161C-2		1957	59.66	59.35	0.13	
1490	G(B)954	61	1829	11–59.78	176–00.73	0.12	1824
	FG162C-1		1659	12–00.31	00.49	0.14	1648, 1711
	162-C2		1704	00.29	00.32	0.12	
1491	G(B)955	62	1830	11–59.61	177–01.12	0.19	1802, 1920
	FG163C-1		1712	59.72	00.65	0.19	1616, 1740
	163C-2		1717	59.72	00.88	0.18	
1492	G(B)956	63	0232	12–00.16	178–01.58	0.38	0356
	FG164C-1		0116	11–59.92	01.74	0.60	2246, 0356
	164C-2		0121	59.93	02.02	0.62	

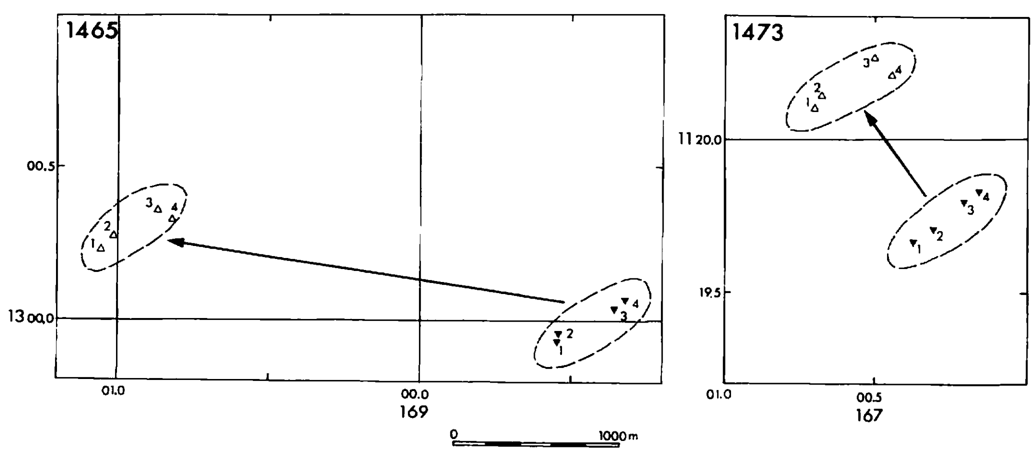


Fig. II-2 Examples of drift of the freefall grabs. Inverse solid triangles indicate the throw-in position and open triangles the pickup position.

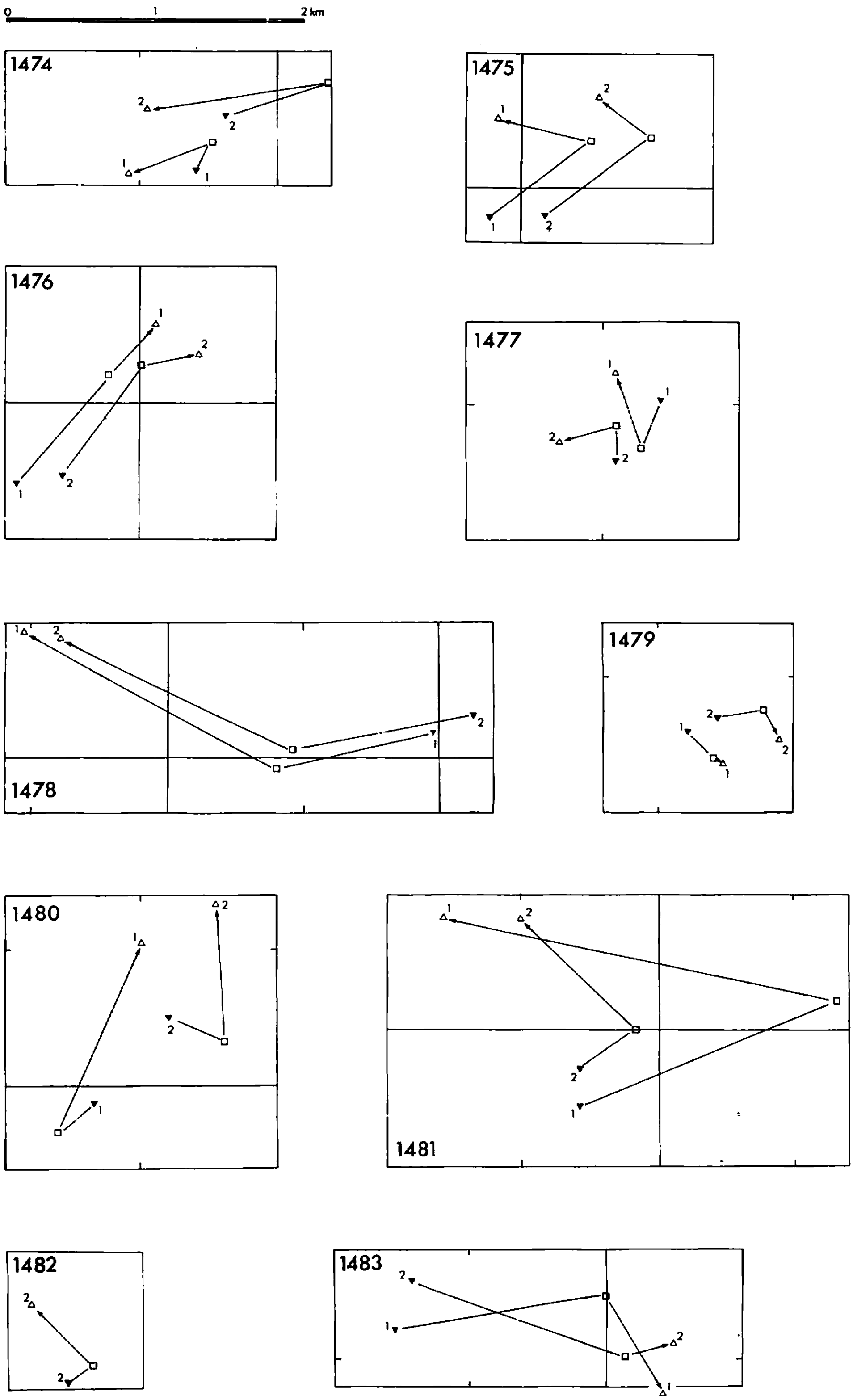
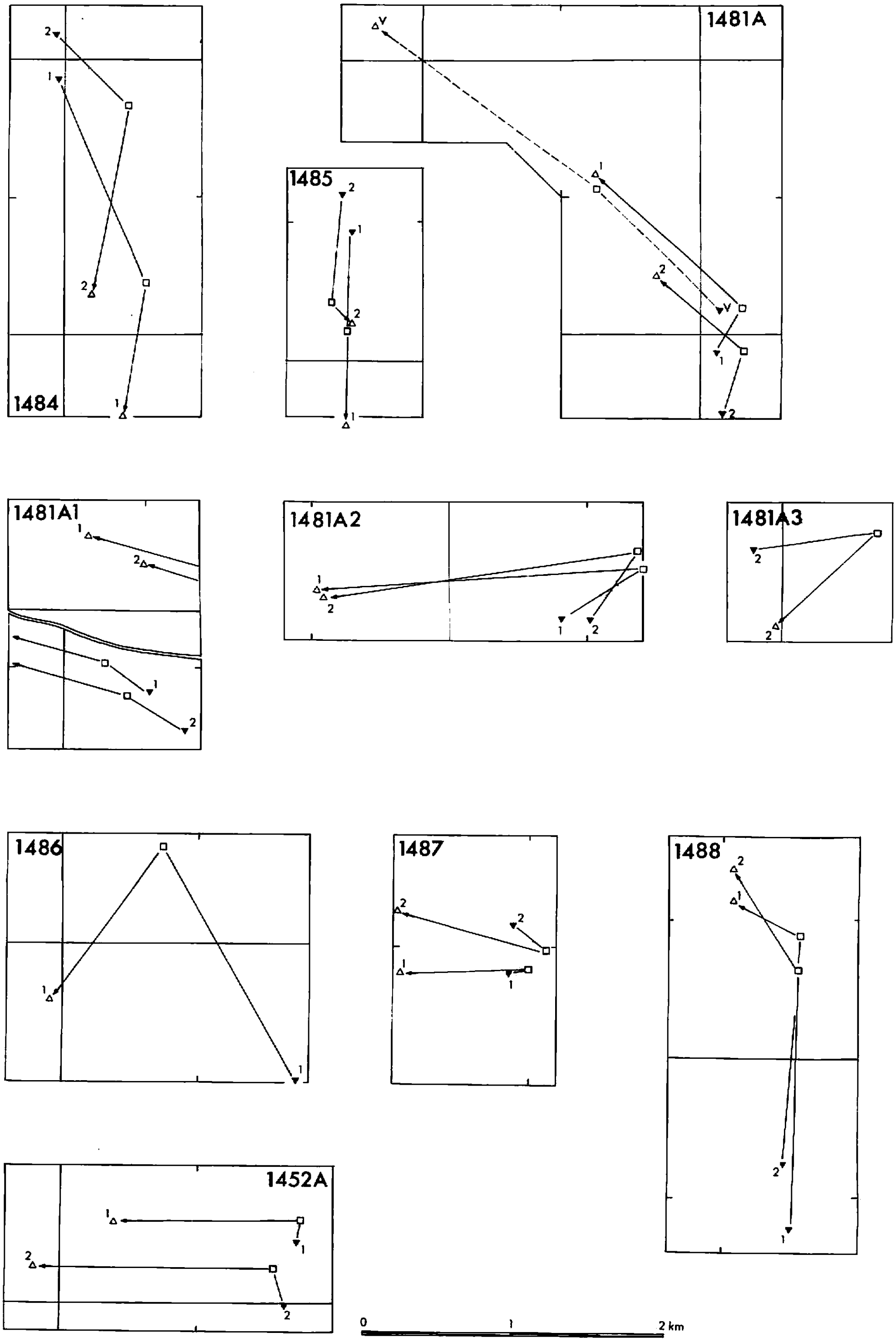


Fig. II-3(a)

Fig. II-3 Drift pattern of the freefall grabs. Symbols as in Fig. II-2. Squares show coming up positions, which were observed only in the later half of the cruise.



1484
1485
1481A
1481A1
1481A2
1481A3
1486
1487
1488
1452A
0
1
2 km

Fig. II-3(b)

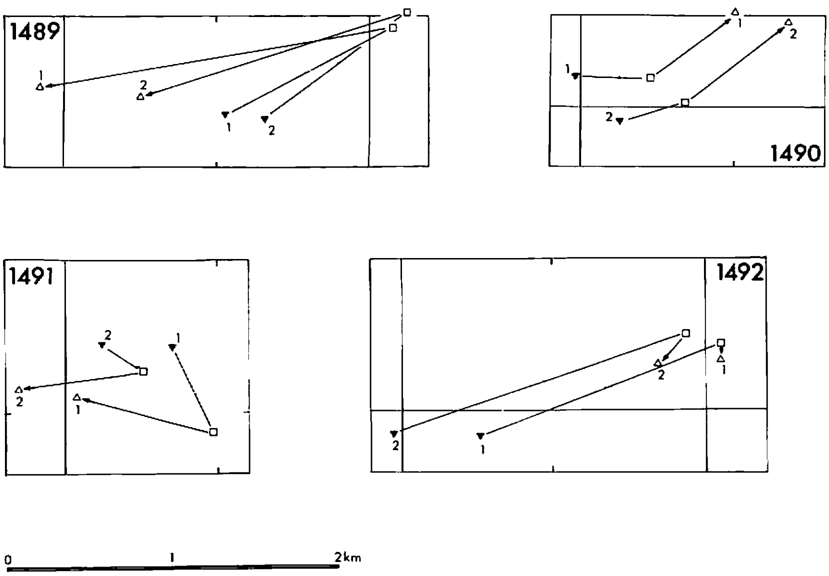


Fig. II-3(c)

curvature and also a vertical component of velocity. The time scale of a freefall sampling work and the characteristic dimension of the drift of a grab could justify the assumptions, and subsurface currents in a deep-sea basin may not have large vertical velocity. In those conditions, the bottom-hitting point of a grab lies under the segment of the line from the throw-in point to the coming up point because the vertical velocity of the grab becomes soon constant as described below, and the position of the bottom-hitting point divides this segment at the rate of the falling speed to the rising speed of the grab.

Let's v_{dn} and v_{up} be the falling speed and the rising speed, respectively. Then the horizontal displacement due to subsurface currents is given by

$$L = \frac{D}{v_{dn}}V + \frac{D}{v_{up}}V,$$

where D is depth and V is the integrated velocity of subsurface currents. Therefore the bottom-hitting point is at a distance of DV/v_{dn} from the throw-in point on the segment. As L is given as the length of the segment from the throw-in point to the coming up point, we can estimate the bottom-hitting point if the ratio of v_{dn} to v_{up} is known.

Now consider the motion of a freefall grab. The grab used in the cruise is 33 kg in weight and 60 cm in breadth, and has buoyancy of +20 N. The sinking grab has two 20 kg ballasts. Let's a grab be a hollow ball of 0.2 m radius with 33 kg weight. Its buoyancy by $4/3\pi r^3 \rho g$ is 340 N, where r is radius, ρ is the water density, and g is the gravity acceralation. Consequently the force to the sinking grab is 380 N in the downward direction, and that to the rising grab becomes 20 N in the upward direction. The Reynolds number defined by $R = \rho r v/\mu$ reaches $10^5 v$, where v is velocity and μ is the water viscosity. The viscous resistance becomes negligible under the condition of the Reynolds number greater than one.

The equation of motion of a grab is expressed by

$$m\frac{\mathrm{d}v}{\mathrm{d}t} = \mathrm{K} - \frac{\pi}{4}r^4\rho v^2,$$

where m is mass of the grab, K is an external force, and v, r, and ρ are same defined above. This equation leads the solution

$$v = \frac{2}{r}\sqrt{\frac{\mathrm{K}}{\pi\rho}}\,\frac{\exp\left(\frac{r}{m}\sqrt{\pi\rho\,\mathrm{K}t}\right) - 1}{\exp\left(\frac{r}{m}\sqrt{\pi\rho\,\mathrm{K}t}\right) + 1},$$

the final speed

$$v_0 = \frac{2}{r}\sqrt{\frac{\mathrm{K}}{\pi\rho}},$$

and the time till reaching this speed

$$t_{\mathrm{f}} = \frac{m}{r\sqrt{\pi\rho\,\mathrm{K}}}\log\frac{\mathrm{e}+1}{\mathrm{e}-1}.$$

Using following values:

- m mass of a freefall grab, 73 kg in falling and 33 kg in rising,
- r radius of a freefall grab, 0.2 m,
- ρ water density, 1000 kg/m^3,
- K external force, 380 N in falling and 20 N in rising,

we obtain the falling speed v_{dn} and the rising speed v_{up} by

$$v_{\mathrm{dn}} = 210 \text{ m/min}$$

and

$$v_{\mathrm{up}} = 48 \text{ m/min},$$

and also the average speed v_{av} by

$$v_{\mathrm{av}} = \frac{2v_{\mathrm{dn}}v_{\mathrm{up}}}{v_{\mathrm{dn}} + v_{\mathrm{up}}} = 78 \text{ m/min}.$$

The time constant t_{f} is less than 1 sec in both cases.

The large falling speed compared with the rising speed by the ratio of 4.4 means that the bottom-hitting point is near the throw-in point, and then supports that the sampling position is regarded as the throw-in position. As a matter of fact, maximum distance between the throw-in position and the coming up position is about 1 n.m. This yields only 0.2 n.m. distance from the throw-in position to the estimated bottom-hitting point, which may be included in the error of the positioning. This leads to the conclusion that it is reasonable to determine the sampling position of a freefall grab as its throw-in position.

Summary

In this Chapter was presented the UT dependence of satellite fixes of NNSS positioning during the GH79–1 investigation and the stationary positions with estimated errors. The bottom-hitting point of a freefall grab sampler was also estimated based on its freefall motion.

Satellite fixes occurred most often between 5 UT and 12 UT, and 17 UT and 23 UT in the earlier half (day 21 to 34), and between 3 UT and 11 UT, and 15 UT and 23 UT in the later half (day 47 to 62). The recalculation error in those hours is statistically less than 0.3 n.m. in the worst case.

The bottom-hitting point of a freefall grab lies under the segment of the line from the throw-in point to the coming up point under the assumptions that subsurface currents are invariant with time and do not have a curvature and vertical component of velocity. The distance from the throw-in point along the segment is controlled by the ratio of the falling speed to the rising speed. The equation of the freefall motion gives the ratio of about 4.4. The large falling speed compared with the rising speed leads the conclusion that the bottom-hitting point (sampling position) is regarded as the throw-in position.

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