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Observation on the Volume transport of the Kuroshio South of Japan

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Abstract

The Kuroshio south of Japan shows a clear bimodal path characteristic between large meander path and no large meander path. It has been pointed out by many studies that the volume transport of the Kuroshio is an important parameter which controls the selection of the bimodal Kuroshio path. However, a clear relationship between the intersity of volume transport and the selection of the Kuroshio path has been not clarified yet. From these view points, we have made hydrographic observations of the Kuroshio south of Japan over the period of 1983-1988. In this report, we present the basic data of geostrophic volume transport referred to 1500 db and the volume transport observed by suspended current meter from the vessel. It is shown that there exists a remarkable variation in volume transport. The geostrophic transport is relatively larger in period of no large meander (70.5±9.8 Sv) than that in large meander (61.8 ±20.0 Sv). The largest transport is observed during the transition period from no meander path to large meander path in winter of 1986.

Key words: volume transport, current velocity, the Kuroshio, western boundary current

1. Introduction

The Kuroshio takes one of two stable paths as it flows along the south coast of Japan: one is a no large meander path nearlly parallel to the southern coast of Japan and the other is a large meander path accompanied by a large cold water mass off Enshu-Nada.

So far, many theoretical studies on the path dynamics of the Kuroshio have been carried out[1),2),3)]. In these studies, because the large meander of the Kuroshio is considered essentially as a Rossby wave in the zonal mean flow, the Kuroshio takes the large meander path when the volume transport of the Kuroshio is relatively small. However, some recent studies[4),5),6)] have demonstrated that if the coastal and bottom topographic effects are considered, the large meander path is formed when the volume transport is relatively large. To clarify the dynamics of the Kuroshio, we should know the real relationship between the intensity of volume transport and the selection of the path. From this view point, we have been carried out the hydrographic observations on the Kuroshio and obtained the volume transport data by the geostrophic approximation over the period of 1983-1988. Furthermore, we have observed the volume transport by use of suspended current

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meter from the vessel. In the present paper, all data sets of the geostrophic flow and volume transport by the observations are presented.

2. Observation

All the observations have been carried out by the training & research vessel Seisui-maru of Mie University, of which details are tabulated in Table 1. Temperature and salinity were observed by CTD and the geostrophic currents referred to 1500 db and 3200 db were estimated. The volume trasport was also estimated from the velocity data observed by the suspended Aanderaa current meter from the vessel. The direct current measurements were carried out for 15 minutes for the lowest level and 7 minutes for intermediate layer, and the mean velocity was obtained by subtracting ship drift estimated by Loran C from the observed velocity.

Table 1. Observations made by the Seisui-maru for the present study

Cruise names	Periods	No. of observational lines	Main instruments used in observations
83MAY	8–12 May 1983	2	CTD
83JUL-1	16–19 Jul. 1983	1	CTD, Aanderaa C.M.
83JUL-2	25–28 Jul. 1983	1	CTD
83OCT	30 Oct.–3 Nov. 1983	2	CTD, Aanderaa C.M.
84JAN	28 Jan.–2 Feb. 1984	2	CTD, Aanderaa C.M.
84APR	16–25 Apr. 1984	3	CTD
84JUL	25–28 Jul. 1984	1	CTD
84SEP	14–19 Sep. 1984	2	CTD
84NOV	21–30 Nov. 1984	2	CTD
85MAY	17–24 May 1985	2	CTD, Aanderaa C.M.
85JUL-1	14–17 Jul. 1985	1	CTD, Aanderaa C.M.
85JUL-2	21–25 Jul. 1985	1	CTD
85OCT	19–21 Oct. 1985	1	Aanderaa
86MAY	10–16 May 1986	2	CTD, Aanderaa C.M.
86JUL-1	14–17 Jul. 1986	1	CTD
86JUL-2	23–26 Jul. 1986	1	CTD, Aanderaa C.M.
86NOV	28 Nov.–5 Dec. 1986	2	CTD, Aanderaa C.M.
87JUL-1	16–18 Jul. 1987	1	CTD, Aanderaa C.M.
87JUL-2	24–26 Jul. 1987	1	CTD, Aanderaa C.M.
87NOV	30 Nov.–5 Dec. 1987	1	CTD
88MAY	8–16 May 1988	1	CTD, Aanderaa C.M.
88OCT	27 Oct.–3 Nov. 1988	2	CTD

3. Velocity and volume transport of the Kuroshio

All the velocity data set obtained by the geostrophic estimation and the suspended Aanderaa current meter are shown in Fig. 1. The location of each observational lines are displayed together with the main Kuroshio axis and velocity fields compiled by Japan Hydrographic Department.

The observed volume transport is tabulated in Table 2. The volume transport by the geostrophic

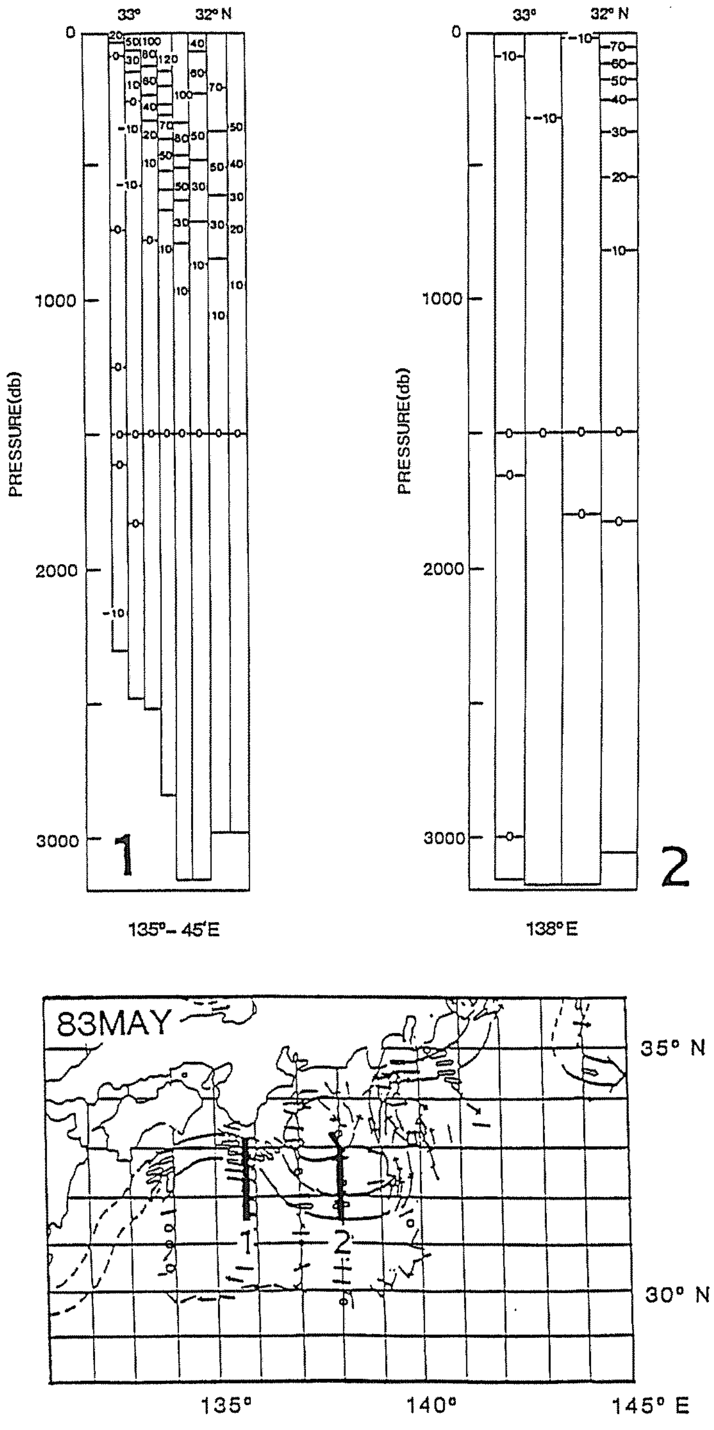
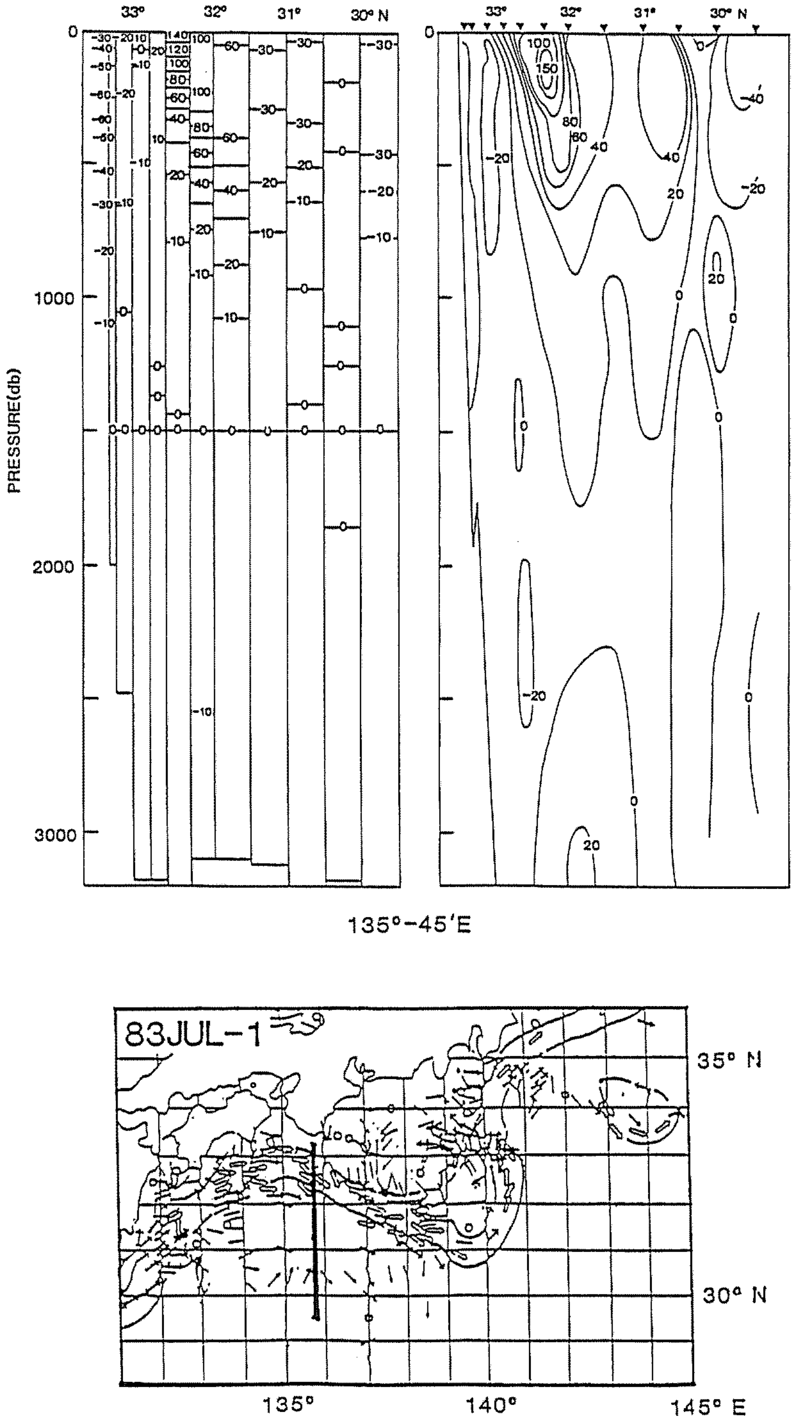


Fig. 1. Vertical section of geostrophic velocity (panels with straight line contour) and the velocity by suspended current meter (penels with smoothed line contour). The location of the vertical section is shown by solid line in the bottom map, where location of the main Kuroshio axis and velocity vectors by Japan Hydrographic Office are also shown.



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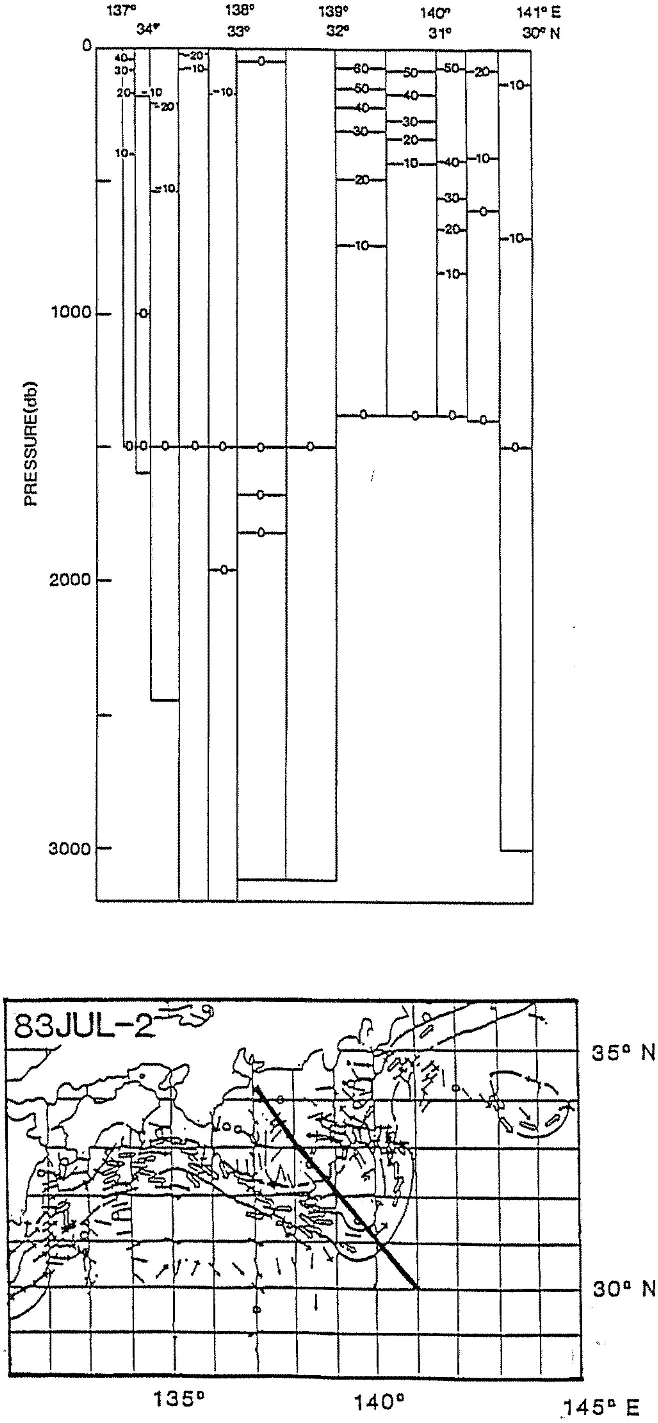

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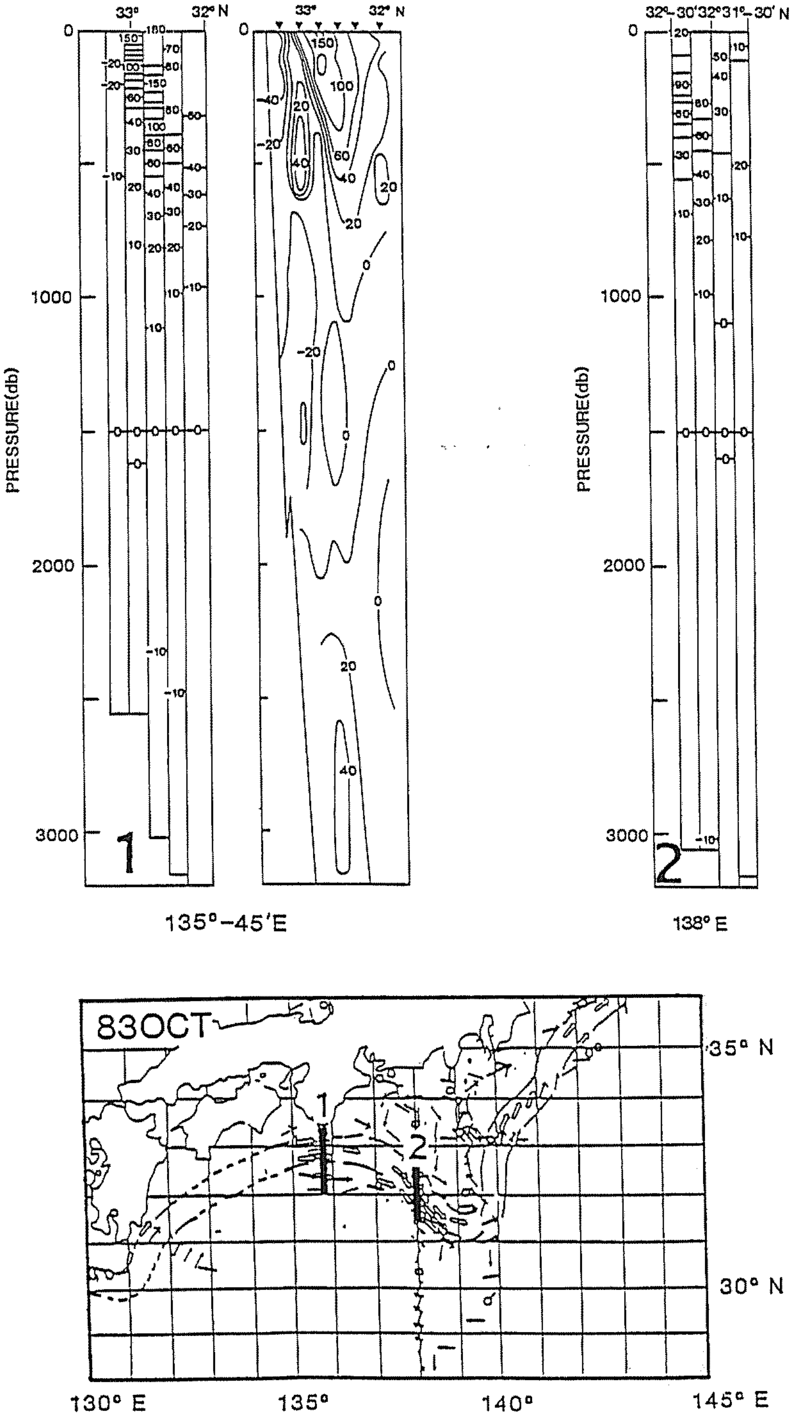

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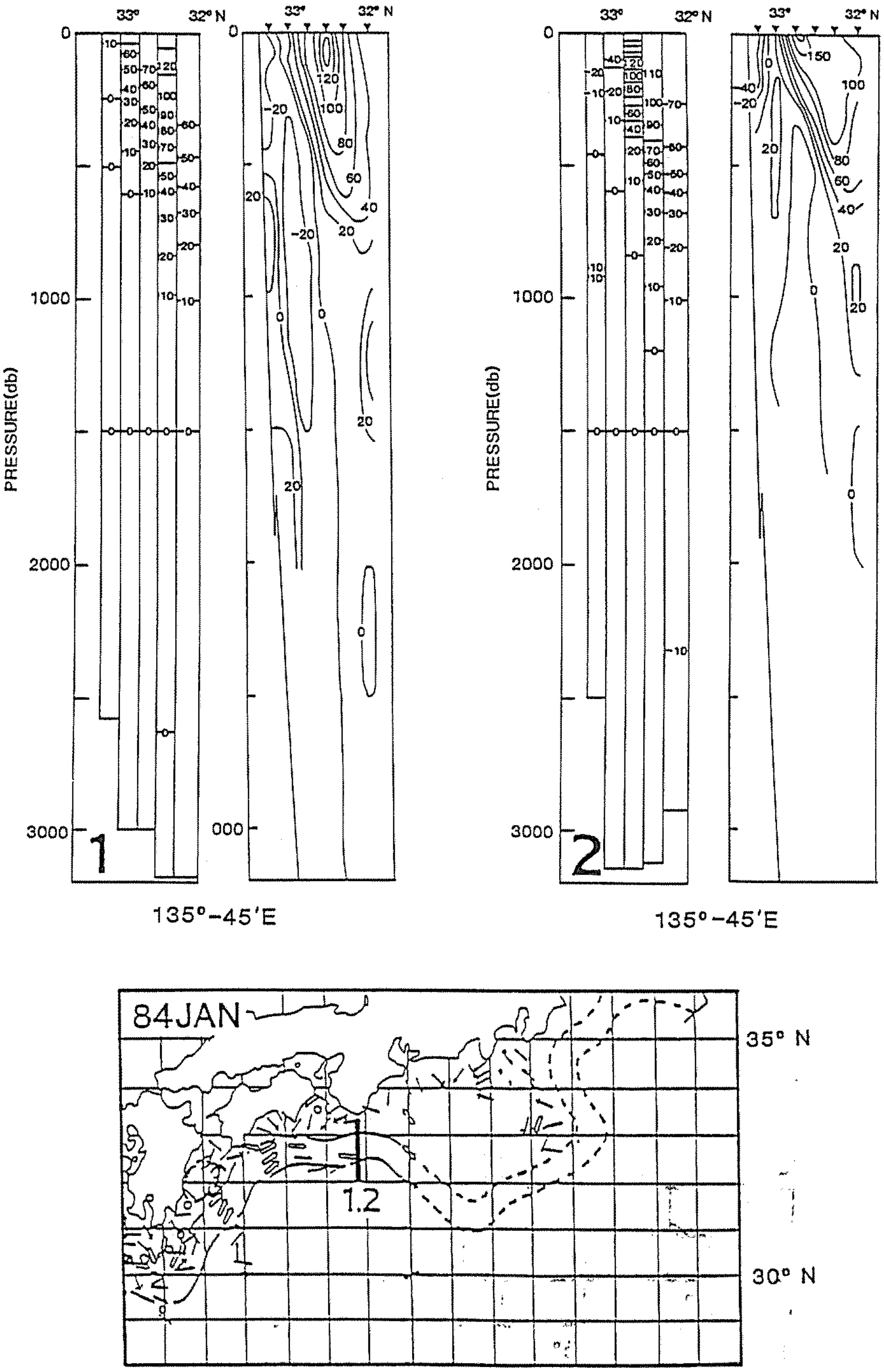

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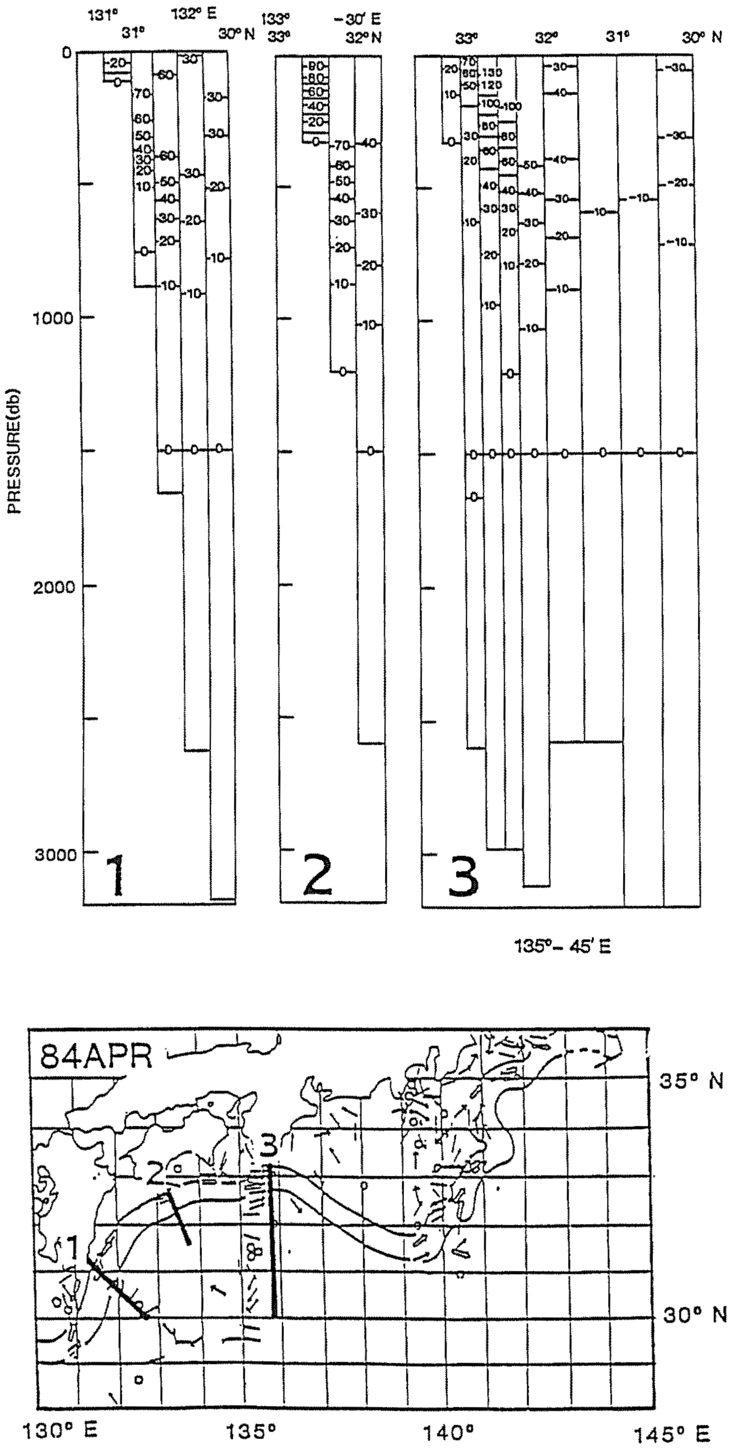

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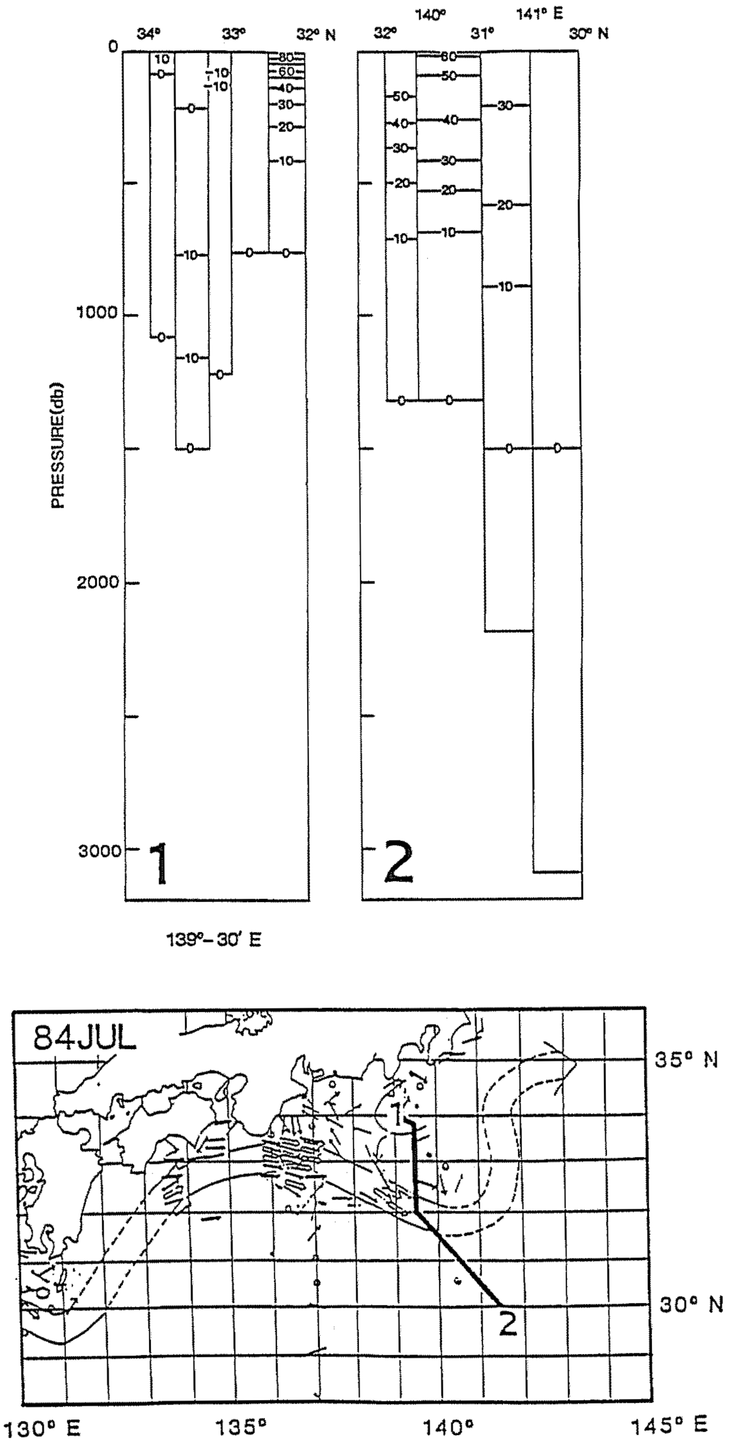

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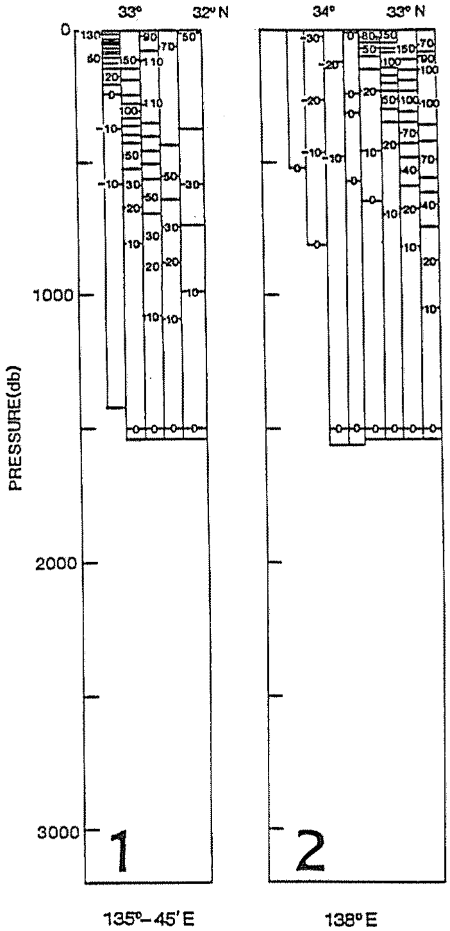

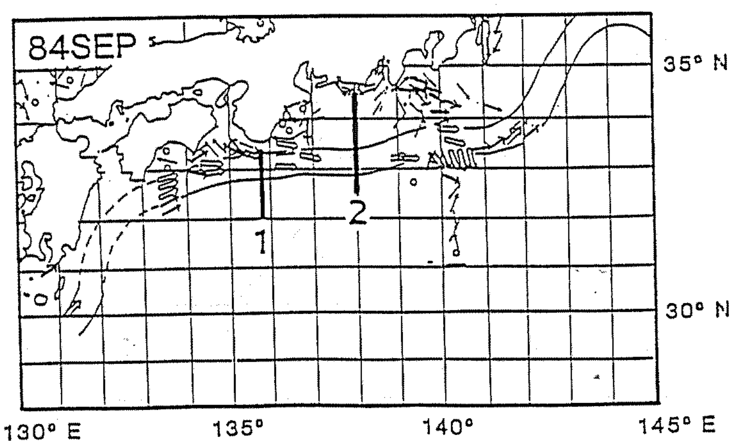

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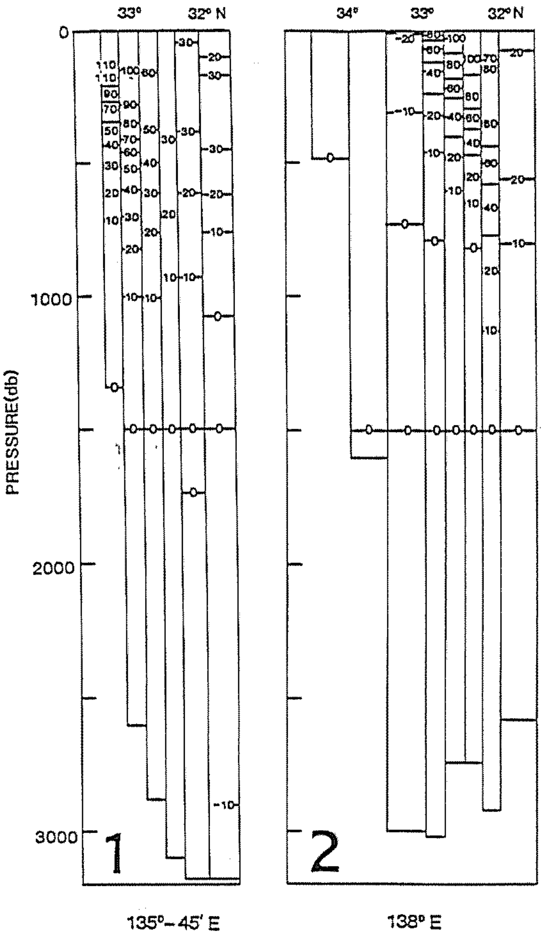

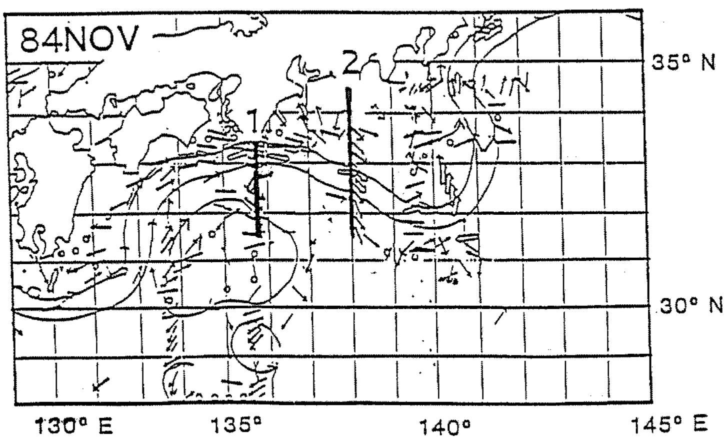

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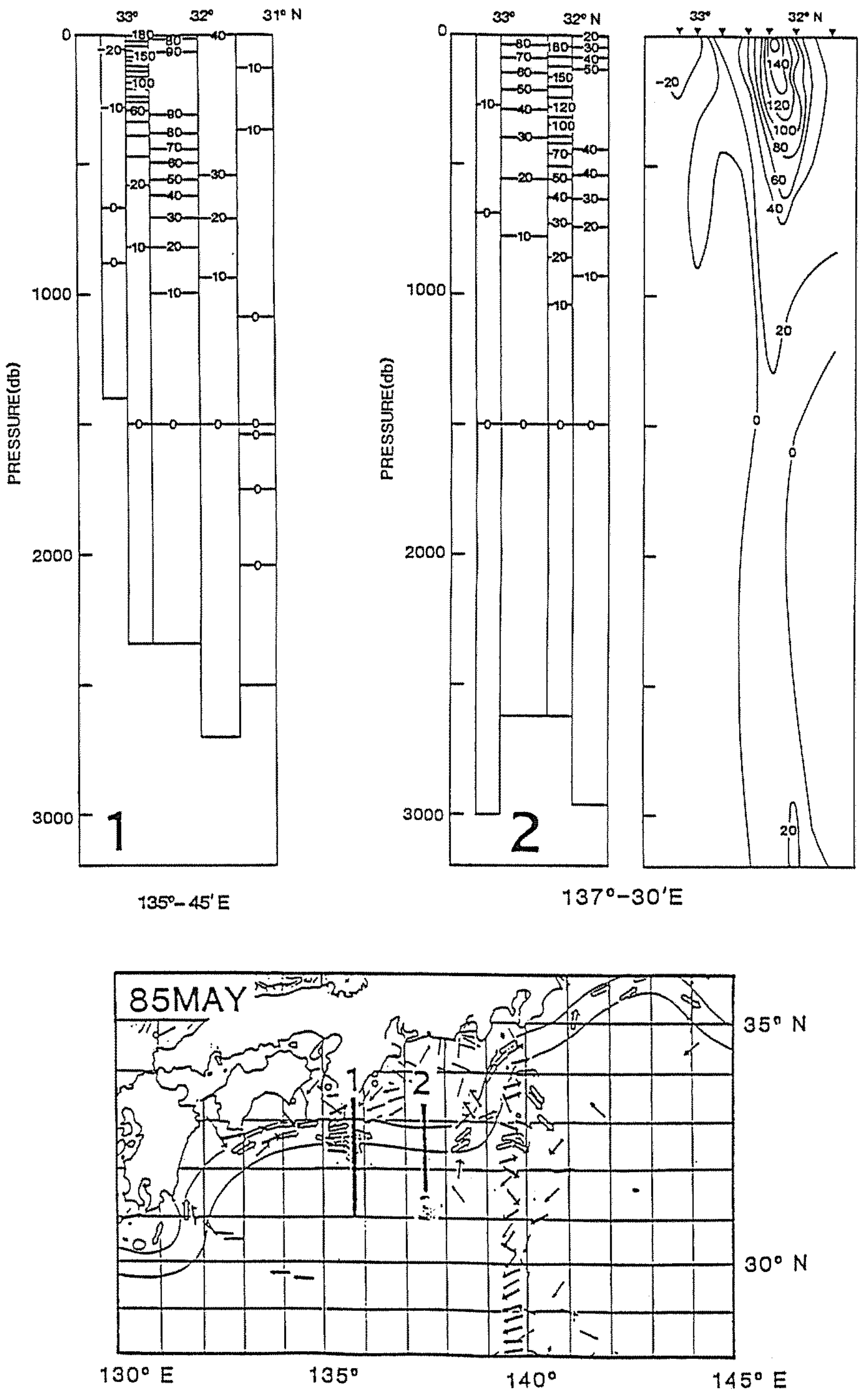

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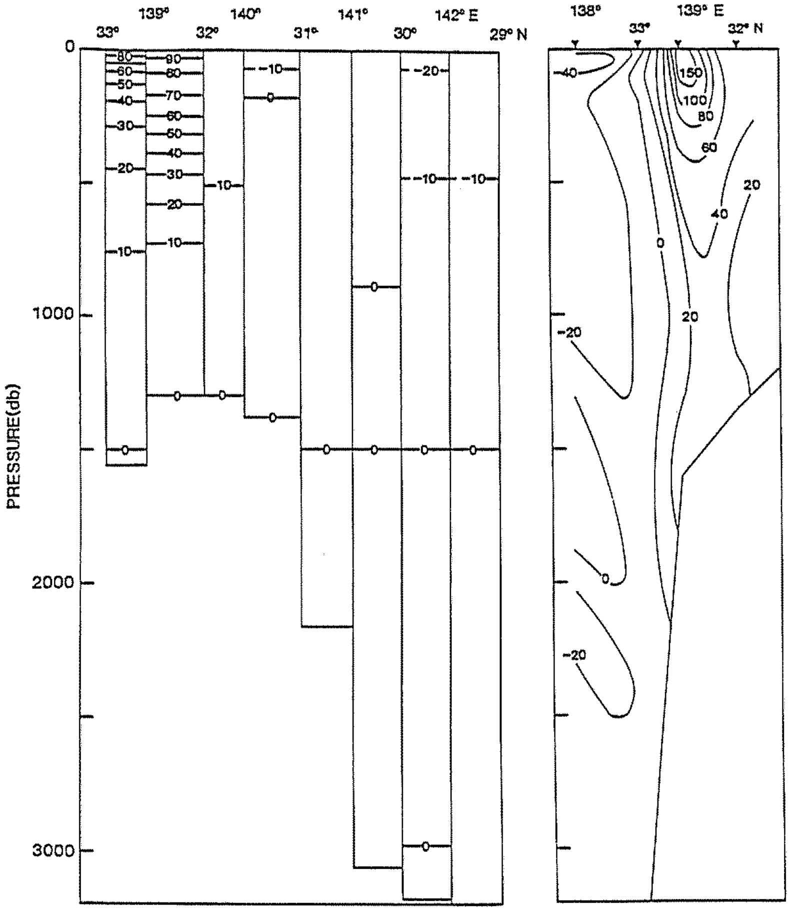

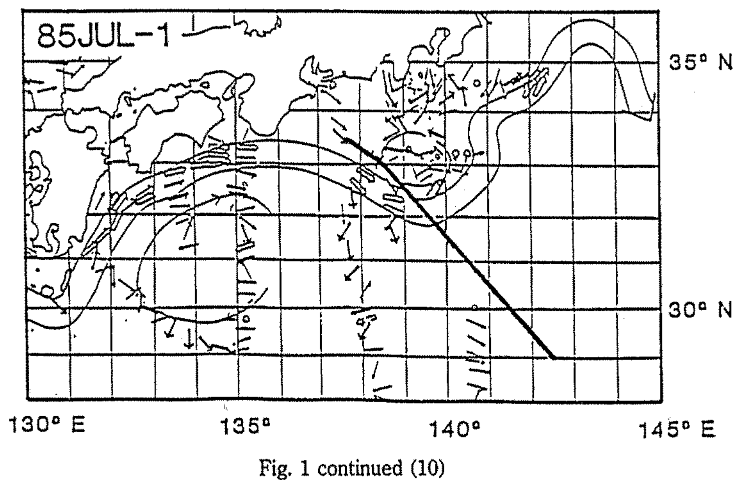

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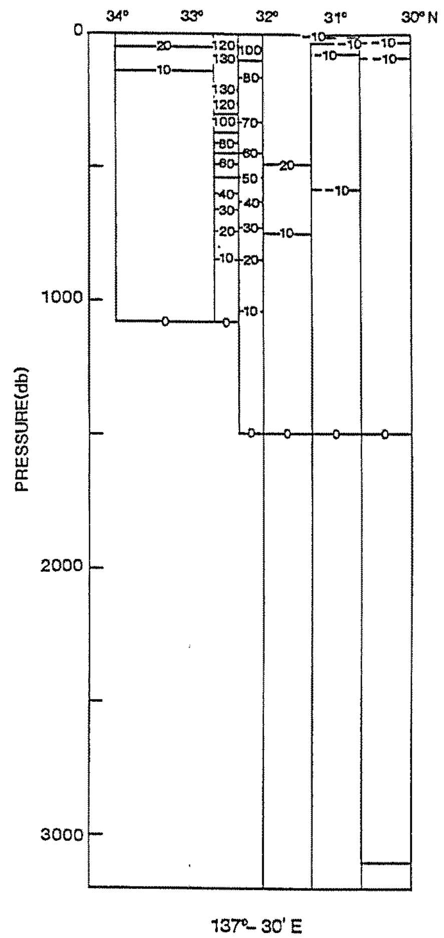

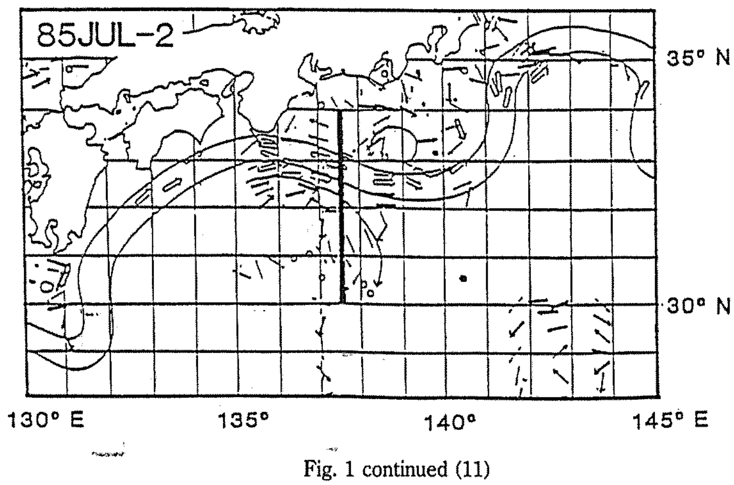

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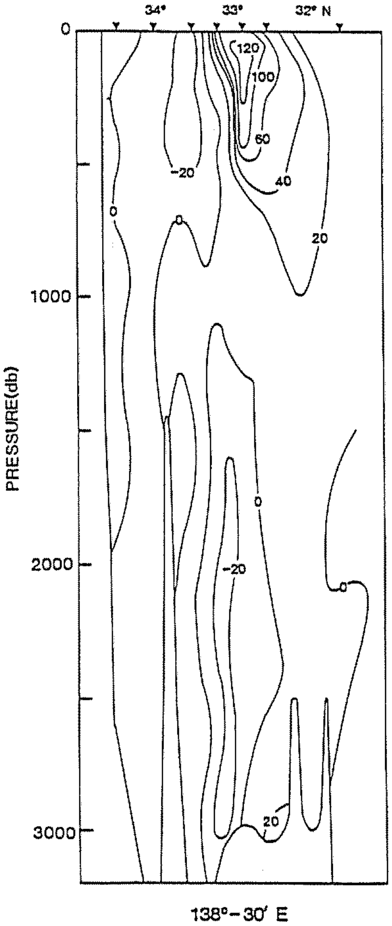

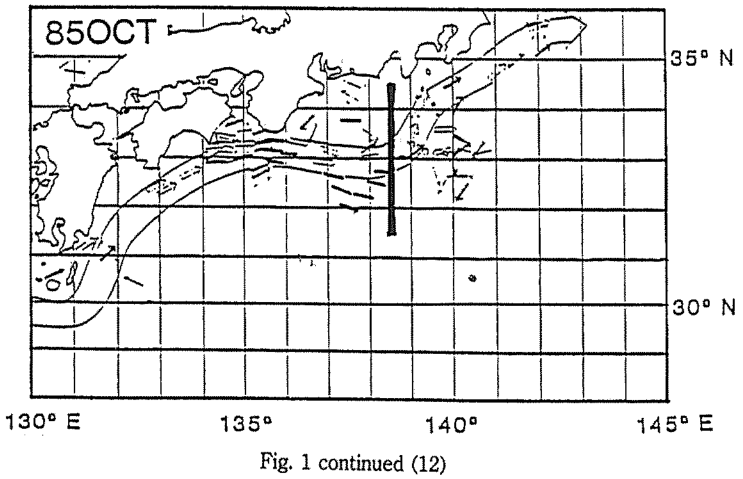

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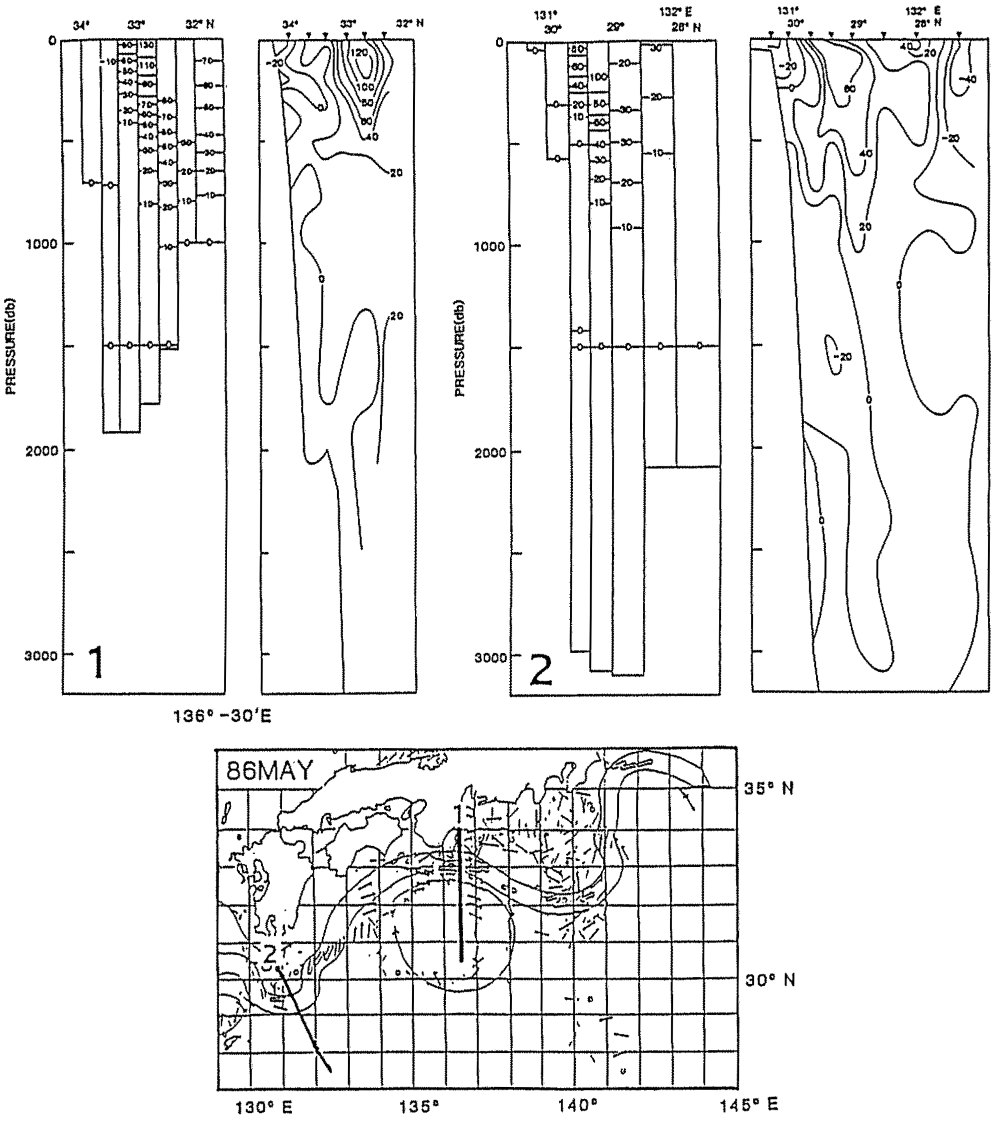

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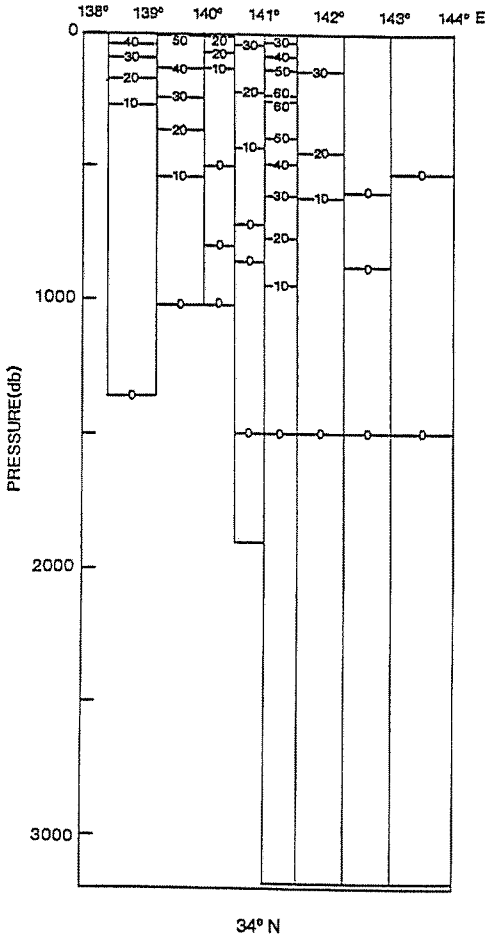

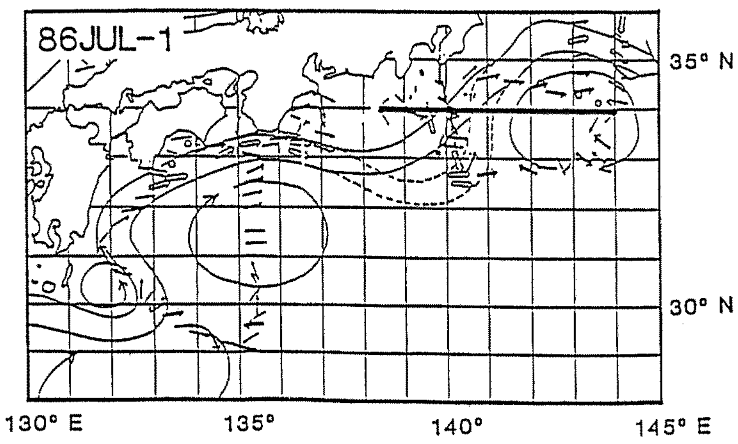

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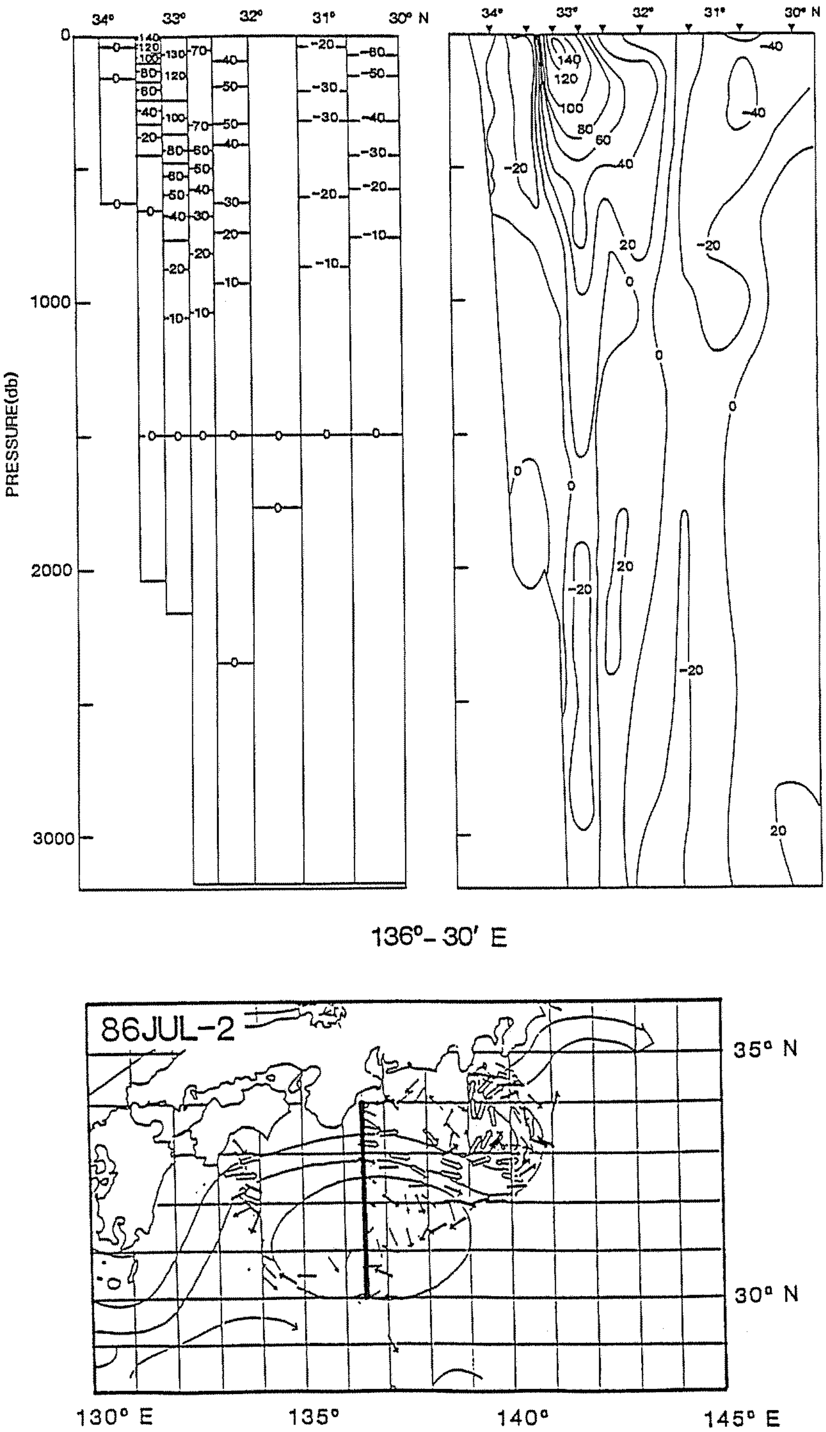

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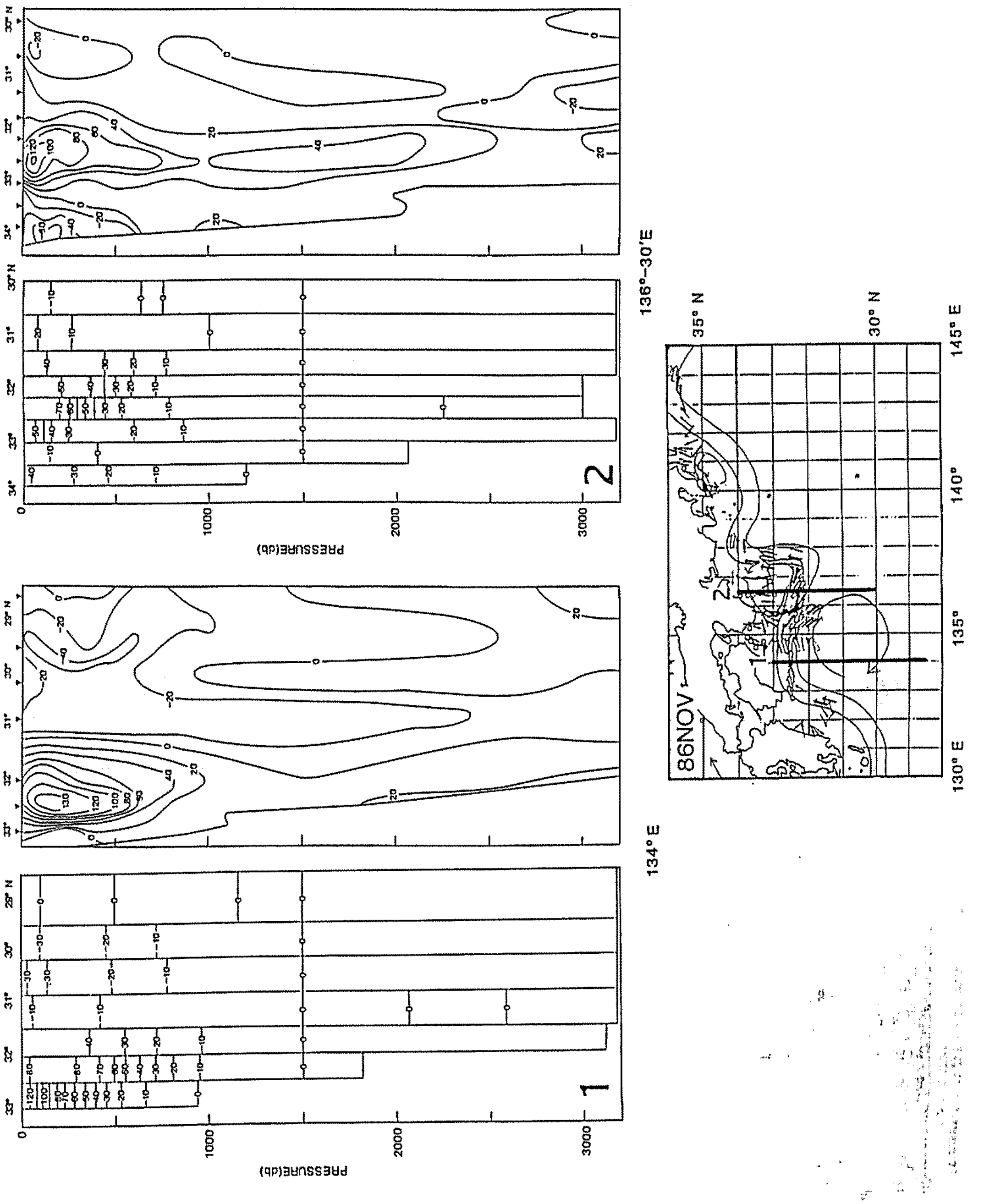

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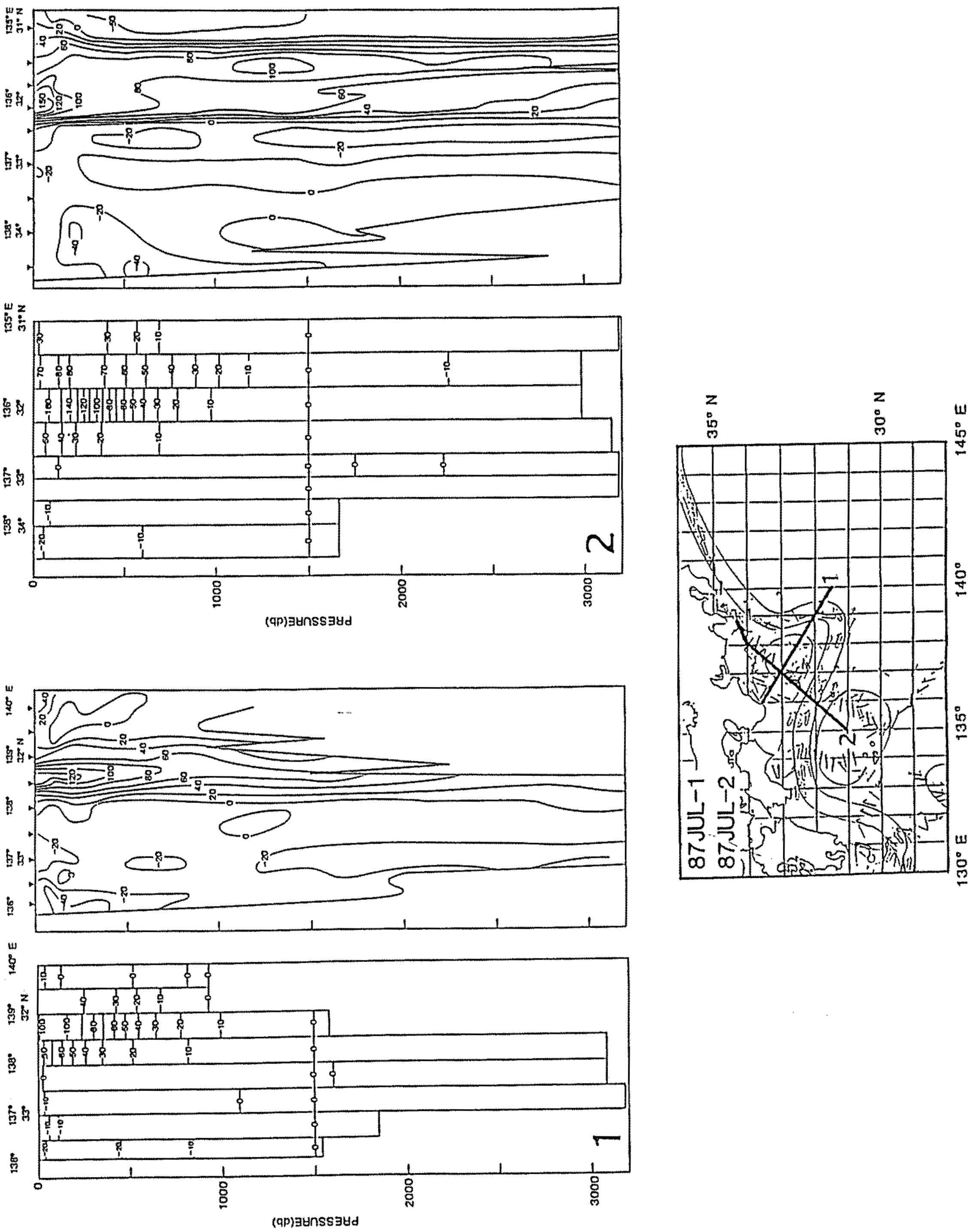

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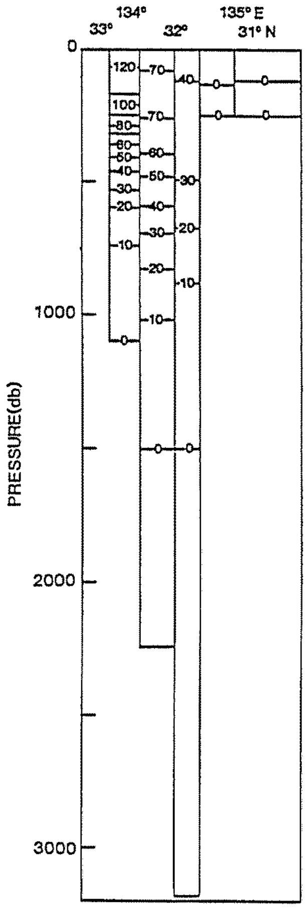

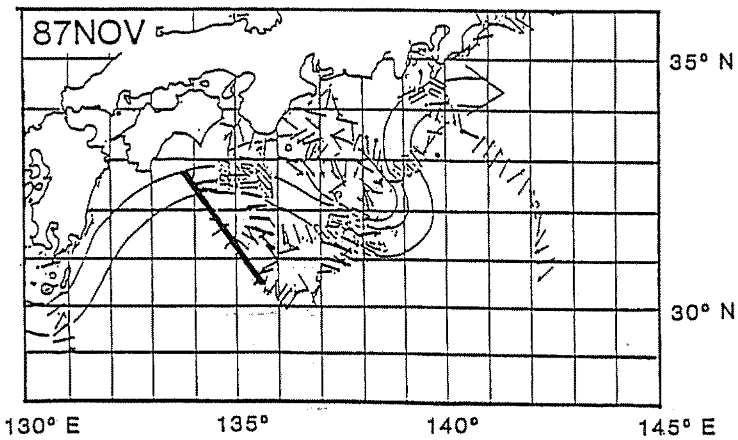

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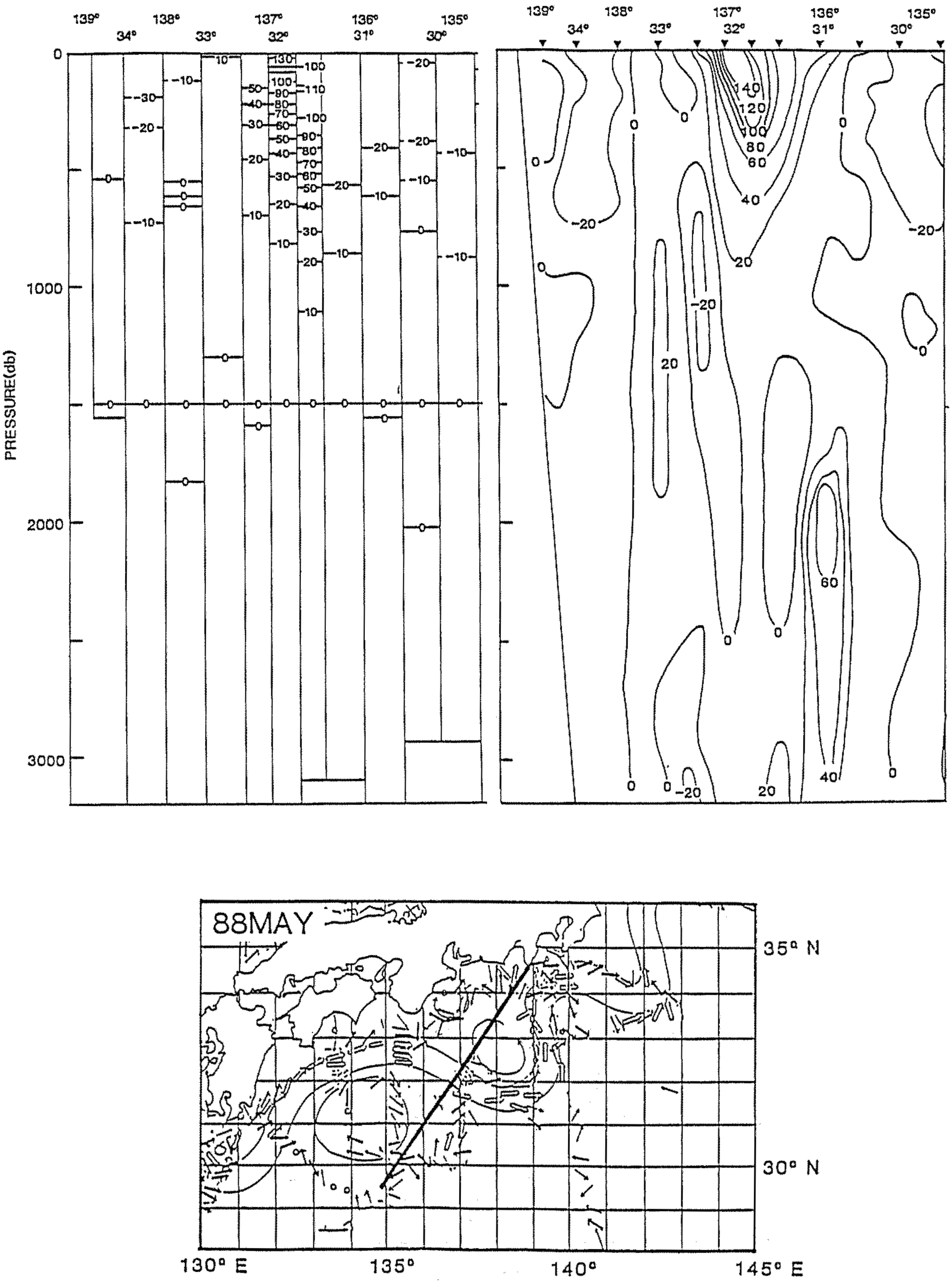

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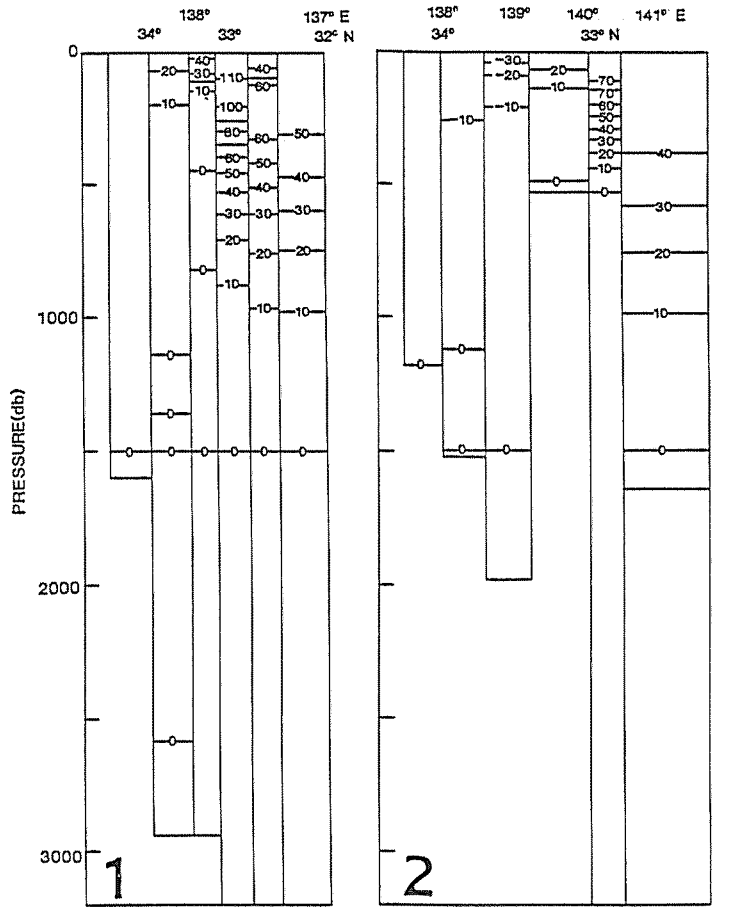

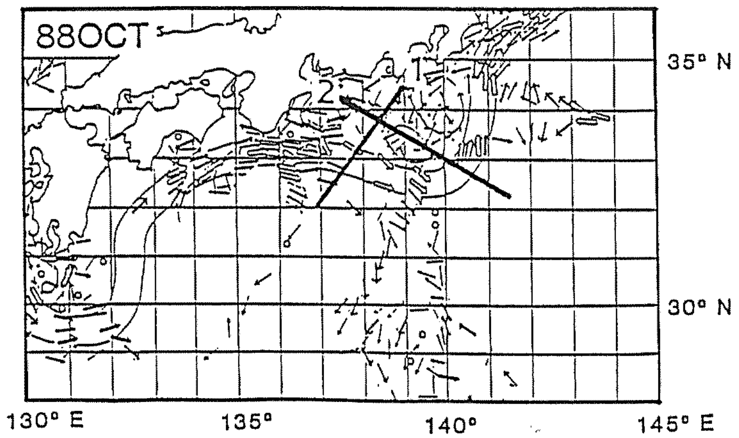

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Table 2. Observed volume transport (in Sv) of the Kuroshio

Cruise name	Geostrophic volume transport referred to 1500 db and 3200 db					Volume transport by Aanderaa current mater	
	Downstream transport		Upstream (counter) transport		Downstream transport around main current axis	Downstream transport	
	1500 db	3200 db	1500 db	3200 db	1500 db	1000 db	3200 db
83MAY	70.23	70.71	−1.47	−9.84	70.12	—	—
	18.11	20.48	−7.03	−9.26	16.04	—	—
83JUL-1	87.09	90.50	−23.66	−35.85	87.08	—	71.6
83JUL-2	60.24	61.77	−14.25	−19.19	57.92	—	—
83OCT	63.78	64.87	−6.72	−13.05	63.78	—	60.7
	38.00	38.00	−0.03	−4.62	38.00	—	—
84JAN	50.27	52.60	−0.24	−3.39	48.95	—	55.9
	51.82	55.97	−2.43	−7.50	50.15	—	54.0
84APR	74.32	78.28	−16.52	−25.33	73.38	—	—
	42.19	42.19	−0.02	−2.47	42.19	—	—
	38.30	38.30	0.00	−0.39	38.30	—	—
84JUL	67.03	67.03	−8.46	−12.02	62.36	—	—
84SEP	68.28	68.28	−1.85	−1.85	64.97	—	—
	49.89	49.89	−8.16	−8.16	49.89	—	—
84NOV	67.57	69.56	−0.09	−8.78	67.57	—	—
	55.42	57.95	−5.56	−11.76	51.89	—	—
85MAY	83.25	83.27	−2.34	−6.72	83.23	—	—
	75.94	77.33	−0.29	−8.67	75.94	—	75.0
85JUL-1	63.35	67.04	−16.60	−18.19	63.35	—	66.0
85JUL-2	64.41	68.54	−12.15	−14.87	64.41	—	—
85OCT	—	—	—	—	—	67.5	81.0
86MAY	74.82	74.82	−1.53	−1.71	73.43	99.0	154.5
	51.02	51.96	−6.59	−10.94	50.84	77.6	97.9
86JUL-1	60.35	61.18	−4.58	−13.80	56.77	—	—
86JUL-2	76.73	84.97	−44.59	−49.93	76.69	78.3	102.3
86NOV	66.20	72.73	−14.09	−23.86	65.87	95.3	116.3
	69.78	79.87	−35.28	−35.61	69.78	130.4	218.5
87JUL-1	60.79	61.60	−12.79	−17.40	60.11	127.2	143.7
87JUL-2	92.31	92.38	−14.79	−28.12	92.03	88.7	343.7
87NOV	58.89	58.89	−0.33	−3.99	58.82	—	—
88MAY	89.06	101.19	−41.44	−58.09	87.07	—	92.6
88OCT	58.42	58.42	−10.20	−10.20	57.10	—	—
	78.70	78.74	0.00	−11.12	78.70	—	—

estimation is relatively smaller than that by the Aanderaa current meter. The maximum volume transport is found in winter of 1986–1987. During this period, the Kuroshio pass was changed from no meander path to large meander path.

The averaged volume transport during no meander path and large meander path is tabulated in Table 3. The geostrophic transport is relatively larger in period of no large meander (70.5 ± 9.8 Sv) than that in large meander (61.8 ± 20.0 Sv). The volume transport estimated from the velocity by the suspended current meter

Table 3. Mean volume transport (in Sv) over four seasons, over the period of large meander path and no large meander path

Periods	Mean geostrophic volume transport referred to 1500 db and 3200 db						Mean volume transport by Aanderaa current meter	
	No. of obs. lines	Downstream transport 1500 db	Downstream transport 3200 db	Upstream (counter) transport 1500 db	Upstream (counter) transport 3200 db	Downstream transport around main current axix 1500 db	No. of obs. lines	Downstream transport 3200 db
Winter	2	51.1	54.3	−1.3	−5.4	49.6	2	55.0
Spring	10	61.7±21.8	63.9±23.4	−7.7±12.7	−13.4±21.9	61.1±21.9	4	105.0± 29.8
Summer	9	70.3±11.5	72.8±12.1	−16.9±11.0	−23.3±11.8	69.0±12.3	5	145.5±102.9
Autumn	11	61.4±10.5	63.4±11.9	−7.2±10.0	−12.1± 9.3	60.6±10.6	4	119.1± 60.7
Large meander	18	60.0±18.8	61.8±20.0	−8.7±10.5	−14.5±14.3	59.0±18.8	7	117.5± 96.8
No large meander	14	67.6± 9.1	70.5± 9.8	−11.0±13.0	−16.2±12.3	66.8± 9.8	8	113.9± 47.3

shows that the averaged transport in large meander path (117.5±96.8 Sv) is slightly larger than that in no meander path (113.9±47.3 Sv). Because a remarkable deviation in both the periods exists, a clear tendency between the volume transport and the appearance of large meander path is not detected.

The seasonally mean volume transport is also displayed in Table 3. The geostrophic volume transport has a maximum in summer and minimum in winter. This seasonal variation agrees with the surface volume transport estimated by the sea level difference across the Tokara Strait[8]. However, the wind stress has a maximum in winter and minimum in summer to autumn[9),10)]. To see the dynamical background behind of this problem, we must examine the phase difference between the observed geostrophic volume transport and the wind stress. Further specified data analysis based on these data will be reported in a succeeding paper.

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日本南岸の黒潮流量の観測

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日本南岸の黒潮は大蛇行流路と非大蛇行流路との間で明確な二様性を示す。従来の多くの研究から黒潮流量が流路の重要なパラメータであることが指摘されているが，はっきりした黒潮流量の大小とその時の流路の形との関連が得られていない。このような観点から，1983年から1988年の間に黒潮に関する各層観測を行った。この報告では1500 db を無流面とする地衡流および船から係留した流速計による流速値の鉛直分布を提示した。全データの平均から，黒潮流量は非大蛇行期に 70.5±9.8 Sv で大蛇行期の 61.8±20.0 Sv よりも大きいことがわかった。また，黒潮流量は1986年の冬の非大蛇行流路から大蛇行流路への移行期に最大となることが示された。