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THE MEAN CIRCULATION ON GEORGES BANK AS MEASURED BY MOORED CURRENT METERS

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ABSTRACT

Moored current meter measurements of one month to several years duration were made at 27 locations in the Georges Bank region of the New England Continental Shelf from 1975 to 1979. The mean current field based on these measurements is a clockwise circulation on the bank, with strong flow along the southern and northern flanks and weaker, more variable flow at both ends.

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INTRODUCTION

This paper describes the residual circulation on Georges Bank as determined from recent long-term moored current meter observations. The measurements were obtained during several field studies (See Appendix), conducted from 1975-1979, which were designed to investigate the general circulation and sediment-transport processes on Georges Bank and the adjacent shelf. The currents may be divided into 1) a mean current, 2) low-frequency current fluctuations primarily associated with density effects and storms, 3) diurnal and semidiurnal tidal currents, and 4) other higher frequency current fluctuations.

We present a preliminary graphical description of the mean currents. A detailed description of the mean current measurements and a preliminary discussion of some implications of the measurements for pollutant transport and the biological productivity of the region is in preparation.

FIELD PROGRAMS

Current measurements were obtained on Georges Bank and the adjacent shelf between 1975 and 1980 (Table 1). Eulerian (fixed-point) current meter measurements and Lagrangian (tracked drifters) techniques were used. Only subsurface Eulerian results are reported here. Most observations less than 15 m below the surface were made with instruments suspended beneath slack-moored surface-following buoys. Measurements at greater depths were made from taut moorings with flotation as deep as possible to minimize wave contamination, typically 2-3 m above the shallowest instrument. The current meters used were primarily AMF (now EG&G) Vector Averaging Current Meters (VACM) which use Savonius rotor and small vane current sensors. Other instruments used were EG&G 102 film recording meters, Aanderaa meters with small rotors and large vanes, tethered ENDECO propellor meters and - at sites 2, 11, and 12 - a special system developed by Raytheon Inc. using Marsh-McBirney electromagnetic current sensors, self-contained data averaging and telemetry of data ashore (Lobecker et al., 1978). Beardsley et al. (1977) present a discussion of the errors in the measurement systems. Some sites (No. 11, for example) were maintained as long-term stations to monitor currents for several years. Most sites, however, were occupied for six months or less (one month minimum), with the objective of resolving regional circulation patterns and current dynamics.

RESULTS

The mean currents are shown in Figure 1. It should be emphasized that the measurements were not synoptic and the means are based on observations of varying duration made during different seasons. In addition the low-frequency variance of the currents was typically 10 cm/sec (the same as the mean), and thus the flow pattern is not as simple as the mean circulation suggests.

The combined data show a clockwise circulation pattern around Georges Bank. The flow on the southern flank was consistently toward the southwest. The mean flow was strongest near the surface (15 cm/sec at 15 m) and weaker at depth (6 cm/sec at 75 m, 10 m above bottom). On the northern side of Georges Bank, a strong flow toward the northeast of 30 cm/sec was observed. On the northeast peak, this easterly jet weakened, and the mean flow was eastward, southeastward, and then southward around the eastern end of the bank at 5-10 cm/sec. On the crest of the Bank, flow was weak toward the south and southwest.

On the eastern side of Great South Channel, the mean flow was consistently toward the north at 5-10 cm/sec at all depths. The data at station 14 just south of Great South Channel showed westerly flow similar to that along the southern flank. On the western side of the Great South Channel, the moored observations showed little net flow.

DISCUSSION

The current observations generally confirm the pattern sketched by Bigelow (1927) 50 years ago, and more recently by Bumpus and Lauzier (1965) and Bumpus (1973, 1976), with some important modifications. The consistent northerly flow on the eastern side of Great South Channel and the "jetlike" current along the northern flank of the bank were unexpected. The current on the crest of the bank was sluggish. The data suggest that water in depths shallower than approximately 60 m may recirculate.

Flow along the southern flank of Georges Bank probably diverges south of Great South Channel. Most flow continues westward along the shelf, while some turns northerly into the channel. Water from the southern flank of Georges Bank in the westward flowing branch could easily reach the shelf south of Cape Cod in 30 days. The low-frequency variance of the long-shelf current was typically 10 cm/sec; thus intense storms of several days duration or major density effects could cause long-shelf particle excursions of ~50 km and cross-shelf excursions of ~25 km and significantly modify the relatively simple conceptual mean flow pattern for short periods.

Several important questions remain unanswered. The residence time of water and material in the Georges Bank region, the importance of the mean flow pattern in the productivity of Georges Bank, and the source(s) of water flowing along the southern flank are unclear. Although the long-shelf component of the currents is generally well resolved, the important cross-shelf flow which determines on-off bank transport of material and nutrients is weak and less well defined. Seasonal changes in the mean flow and in the currents associated with wind stress and density effects, and the dynamics of the low frequency and high frequency currents, as well as the persistent clockwise flow as around Georges Bank must be addressed.

Some of these questions may be answered, at least in part, as the seasonal and higher frequency variations in the flow are investigated and as the current measurements are examined in relation to the regional hydrography and wind stress. Numerical modeling may help to fill some of the gaps in data coverage and in understanding. Additional current measurements may be required especially in critical regions such as the southeast corner of Georges Bank where existing data are sparse and conflicting.

APPENDIX I

This paper presents data from several field programs which received funding from several sources. The principal investigators have coordinated field efforts to the extent possible. The programs, principal investigators, and supporting agencies are acknowledged here.

1. A long-term current monitoring study initiated in 1975 by the USGS and WHOI (B. Butman, R. C. Beardsley, and J. A. Vermersch 1975-1977; B. Butman and M. A. Noble, 1977 - present. Support from USGS to WHOI continued 14-08-00001-G-197 and 14-08-0001-15615. Support from BLM to USGS MOU AA550-MU6-79, AA551-MU8-24, AA551-MU9-4 and AA551-MUO-18.

2. A moored array on the New England Shelf deployed simultaneously with a pilot Georges Bank current meter array. (R. C. Beardsley, J. A. Vermersch, and B. Butman, 1976) conducted with NSF support. NSF grant to WHOI OCE76-01813. BLM MOU to USGS AA550-MU6-29.

3. A study of bottom currents and sediment transport (B. Butman and M. A. Noble 1976 - present) conducted with USGS-BLM support. BLM to USGS MOU AA550-MU6-29, AA551-MU8-24, AA551-MU9-4 and AA551-MUO-18.

4. A study of hydrography and currents on Nantucket Shoals (R. C. Beardsley and R. A. Limeburner, 1978-1979). Conducted with Sea Grant support. Department of Commerce, NOAA Office of Sea Grant Support, Grants 04-7-158-44104 and 04-8-MO1-149.

5. A study of currents in Great South Channel (J. A. Vermersch, B. Butman, and R. C. Beardsley, 1976-1978) conducted with support from USGS and BLM. BLM MOU AA551-MU8-24, AA551-MU9-4.

6. A study of the physical oceanography of Georges Bank (EG&G Environmental Consultants, R. Scarlet, B. Magnell, D. Frye, and C. Flagg, and Raytheon Company, D. Cook, 1977-1980), supported by BLM.

7. A study of currents on the northern side of Georges Bank as part of the larval herring patch study (R. J. Schlitz, W. R. Wright, S. R. Ramp, 1979) conducted with NMFS support.

8. Support was also provided from NSF (OCE78-19513) to R. C. Beardsley, J. M. Vermersch for preparation of this manuscript.

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Table 1. Description of Eulerian current measurements. The data in this table and in Figure 2 are organized by site number. The primary organization which collected the data is indicated in parentheses next to the site number. The instrument type code is: VACM, AMF Vector Averaging Current Meter; 102, EG&G model 102 current meter; 850, Geodyne model 850 current meter; RCM-4, Aanderaa current meter; Ray, Marsh-McBirney electromagnetic current meter mounted on a special spar buoy fabricated by Raytheon Ocean Systems; ENDECO, Endeco model 174 current meter. The mooring code is: S, surface mooring; SS, subsurface moorings; and Spar, the special Raytheon spar buoy.

Table 1(cont'd)

Site Number	Location	Water Depth (m)	Nominal Instrument Depth (m)	Instrument type	Mooring Type	Measurement Start/Stop Time Yr-Mo/Yr-Mo	Record Length (days)
1 (EG&G)	42°04.5' 67°52.4'	200	10	VACM	S	78-01/78-02 78-07/78-09 79-04/79-06	150
		200	77	102	SS	78-01/78-05 78-05/78-07	277
		200	192	102/ RCM-4	SS SS	77-09/78-05 78-05/78-08 78-11/79-01 79-04/79-07	450
2 (EG&G)	41°59.0' 67°47.0'	85	10	VACM	S	78-01/78-01 78-04/78-07 79-04/79-07	191
		85	44	102	SS	78-04/78-07 79-07/79-09	161
		85	77	102	SS	77-09/78-01 78-04/78-07 79-07/79-09	264
(USGS)	41°59.0' 67°47.1'	85	15	VACM	S	76-04/76-08	114
3 (NMFS)	42°12.5' 66°40.8'	218	79	VACM	SS	78-09/78-11	45
			129	VACM	SS		
4 (NMFS)	42°02.0' 66°40.3'	75	19	VACM	S	78-09/78-11	46
			44	VACM	SS		
5 (NMFS)	41°52.6' 66°41.2'	66	11	VACM	S	78-09/78-11	58
			26	VACM	SS		
			36	VACM	SS		57
6 (EG&G)	41°56.0' 66°20.0'	85	10	VACM	S	79-04/79-07	99
			44	102	SS	79-04/79-05	37
			77	102	SS	79-04/79-08 79-08/79-10	173
7 (USGS)	41°41.8' 66°36.2'	66	51	VACM	SS	78-10/79-03	162
8 (USGS)	41°24.0'	38	15	VACM	S	76-04/76-08	136
9 (EG&G)	41°20.4'	40	35	VACM	SS	78-04/78-08	114
10 (USGS)	41°02.2' 67°33.5'	60	15	VACM	S	78-10/78-12 79-03/79-08	328

Site Number	Location	Water Depth (m)	Nominal Instrument Depth (m)	Instrument type	Mooring type	Measurement Start/Stop time Yr-Mo/Yr-Mo	Record Length (days)
			50	VACM	SS	79-03/79-04 79-08/79-09	116
			56	VACM	SS	78-01/78-05	108
11 (USGS)	40°51.4' 67°24.1'	85	15	VACM	S	75-09/75-12 77-07/77-09 78-05/78-09 78-01/78-03	324
		85	45	VACM	SS	75-05/75-08 75-09/76-01 76-08/78-05 78-10/79-02	1007
		85	75	VACM	SS	75-05/75-07 75-09/76-01 76-08/79-03	1113
		85	10	RAY	Spar	78-06/78-08 78-11/79-02 79-03/79-03	172
		85	44	RAY	Spar	77-11/77-11 78-11/79-02 79-03/79-03	147
		85	77	RAY	Spar	78-06/78-09 78-11/79-02	206
12 (EG&G)	40°53.9' 66°58.2'	85	10	RAY VACM/RAY	S	78-06/78-08 78-09/78-12 78-12/79-05	285
		85	44	RAY 102/RAY	SS	78-06/78-08 78-09/79-01 79-02/79-05 79-05/79-06 79-08/79-10	341
		85	77	RAY RAY 102/RAY	SS	78-12/78-01 78-06/78-08 78-09/79-01 79-02/79-04 79-05/79-10	459
13 (EG&G)	40°43.7' 66°49.0'	200	10	VACM	S	78-09/79-01 79-09/79-01	185
		200	77	102	SS	78-09/79-01 79-01/79-10	375
		200	192	RAY/102/ RCM-4	SS	78-01/78-08 78-00/79-01 79-01/79-04 79-05/79-08	348

Table 1 (cont'd)

Site Number	Location	Water Depth (m)	Nominal Instrument Depth (m)	Instrument type	Mooring Type	Measurement Start/Stop Time Yr-Mo/Yr-Mo	Record Length (days)
14 (EG&G)	40°40.0' 68°42.0'	60	10	VACM	S	78-11/79-01 79-05/79-10	267
		60	35	102	SS	78-11/79-01 79-07/79-10	158
		60	52	102	SS	79-07/79-10	99
15 (USGS)	40°50.8' 68°48.5'	66	10	VACM	S	79-04/79-03	169
		66	51	VACM	SS	78-09/79-01	121
16 (USGS)	40°49.0' 60°0.0'	78	58	VACM	SS	76-04/76-07	99
17 (WHOI)	40°50.8' 69°01.0'	81	10	VACM	S	78-09/78-12	107
		81	32	VACM	S	78-09/79-01	149
18 (WHOI)	40°52.0' 69°11.0'	64	27	VACM	SS	78-09/79-01	146
		64	49	VACM	SS	78-09/79-01	146
19 (WHOI)	41°30.4' 69°35.9'	33	5	ENDECO	SS	79-01/79-03	60
		33	25	ENDECO	SS	79-01/79-03	60
20 (WHOI)	41°36.4' 69°43.8'	33	16	ENDECO	SS	79-07/79-08	41
21 (WHOI)	41°26.0' 69°44.1'	22	10	ENDECO	SS	79-07/79-08	41
22 (WHOI)	41°26.6' 69°59.2'	16	8	ENDECO	SS	79-07/79-08	41
23 (WHOI)	40°59.0' 70°04.0'	22	10	ENDECO	SS	79-07/79-08	41
24 (USGS)	40°42.5' 70°0.5'	41	18	850	SS	76-12/77-02	45
25 (USGS)	40°29.0' 70°30.2'	71	61	VACM	SS	78-11/79-01	106
26 (WHOI)	40°21.7' 71°12.0'	83	38	VACM	SS	76-02/76-07	131
		83	73	VACM	SS	76-02/76-04	67
27 (WHOI)	39°58.9' 71°57.4'	83	38	VACM	SS	76-02/76-08	168

Figure 1. Mean velocities on Georges Bank as measured by current meters. The boldface number at origin of each arrow identifies the position number in Table 1. The number in parentheses indicates water depth, and the number at the tip of each arrow indicates the current meter depth.