

A METHOD FOR CALCULATING TIDAL CURRENT AMPLITUDE AND  
DIRECTION ON GEORGES BANK AND SURROUNDING WATERS

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## Abstract

The ability to predict with certainty the tidal current speed and direction in offshore waters was almost exclusively a problem for physical oceanographers. The publication of the Atlas by Moody et al. (1984) has changed that and placed the data necessary for the calculations within the grasp of any investigator. The currents on Georges Bank are such a dominant feature that any investigation in the area must take them into account.

A method for these calculations, with an example, is presented here for the edification of non-physical oceanographers for their use while working in the Northwest Atlantic.

## Introduction

During the summer of 1986 the Recruitment Processes Task began a 3-year program of juvenile fish habitat ecology studies using the submersible R/V Johnson Sea-Link. These studies focused on specific station locations on the Northeast Peak of Georges Bank. Due to the strong rotary semi-diurnal tidal currents found on Georges Bank, it was necessary to be able to predict the current in order to launch the submarine 'upstream' from the desired station. Submersibles are very limited in their ability to operate against the 50+ cm/sec (1+ knot) currents frequently encountered at the bottom on Georges Bank.

Our work included the placement and frequent inspection of baited fish-traps. This type of procedure could only be attempted during periods of low current, which would greatly impact on the dive schedule, or with an accurately predicted tidal direction.

The following method for the calculation of tidal current amplitude and direction proved extremely useful for our purposes with the submersible and are presented for the evaluation and use of other investigators working in the field.

## Methods

The rotary semi-diurnal tides of Georges Bank are the product of the interaction of several diurnal and semi-diurnal components. For this calculation, only three principal semi-diurnal constituents are used: M2, the principal lunar (12.42 hrs), N2, the larger lunar elliptic (12.66 hrs) and S2, the principal solar (12.00 hrs).

The total current,  $U$ , is produced from the sum of all the constituents as follows:

$$U = \sum_i f u_i \cos(w_i t - \phi_i) \quad \text{Equation 1}$$

where  $i$  is a constituent

$u_i$  is the amplitude (either east or north) (from Moody et al. 1984)

$f$  is the correction for the lunar node (Table 1)

$w_i$  is the frequency of the constituent in degrees per solar hour  
(Table 11)

The phase lag  $\phi_i$  of each constituent is measured from the 0 hour or the beginning of the time series.  $\phi_i$  is related to the Greenwich phase ( $G$ ) and to  $S$ , the longitude of the observation (use 75 for Georges Bank) by the following:

$$\text{Greenwich phase } (G) = \text{Greenwich } (V_0 + u) + w_i S / 15 + \phi_i \quad \text{Equation 2}$$

thus:

$$\phi_i = \text{Greenwich phase } (G) - \text{Greenwich } (V_0 - u) - w_i S / 15 \quad \text{Equation 3}$$

where Greenwich phase ( $G$ ) is found in Moody et al. (1984)

$V_0 - u$  is the time difference (in degrees) between a fictitious moon crossing the Greenwich meridian and the Greenwich 0 hour of the time series. Greenwich ( $V_0 - u$ ) is found using Schureman (1941).

Tidal frequencies and periods are found in Table II. The equilibrium argument ( $V_0-u$ ) is the sum of the values for the year, month, day, and hour found in Schureman's (1941) tables 15-18, pages 210-217.

The method can best be followed with an example of the calculations necessary:

The RV/Edwin Link/Johnson Sea-Link occupied Station 1 near current meter PS (found in figure 1 of Moody et al. 1984) on August 4, 1986. Dive time was scheduled for 1 pm (1300) EDT.

First calculate ( $V_0-u$ ) from Schureman (1941)

	M2	S2	N2
1986	238.1	0	311.0
August	231.12	0	341.34
4	286.86	0	247.66
1300	16.79	30.0	9.72
<hr/>			
Greenwich	772.87	30	909.72
( $V_0-u$ )			

Correct ( $V_0-u$ ) to a compass coordinate by subtracting  $360^\circ$  as needed.

hence:

Greenwich	52.87	30	189.72
( $V_0-u$ )			

Next calculate the fourier coefficients and  $\phi_i$  from Moody et al. (1984)  
 (current meter location P5 using the deep instrument (44 m))

	M2		S2		N2		
	East	North	East	North	East	North	
			+		+		
Amplitude cm/sec	52.4	67.8	+	6.7	+	9.2	11.7
Phase:			+		+		
GREENWICH (G)	143	24	+	158	+	96	349
Greenwich (Vo-u)	-52.8	-52.8	+	-30	+	-189.7	-189.7
S	-145	-145	+	-150	+	-142	-142
Phase lag $\phi_i$	305.1	186.1	+	338	+	124.3	17.3

Substituting into equation 1 results in the following current estimation:

$$U_{\text{east}} \text{ (cm/sec)} = f(52.4) \cos(28.984t - 305) + f(6.7) \cos(30.00t - 338) \\ + f(9.2) \cos(38.438t - 17.28)$$

$$U_{\text{north}} \text{ (cm/sec)} = f(67.8) \cos(28.984t - 186.1) + f(9.3) \cos(30.00t - 229) \\ + f(11.7) \cos(28.439t - 17.28)$$

where:  $f = 0.967$  (correction for the lunar node)

$t = 13$  (1 pm = 1300 = 13th hour)

or:

$U_{\text{east}} = 16.1$  cm/sec

$U_{\text{north}} = -61.7$  cm/sec

Plotting these values as seen in Figure 1, the uncorrected total current amplitude and direction can be determined. In this case the amplitude is 63.8 cm/sec in a direction of 165.4 degrees (i.e., the current flows towards 165.4°).

#### Discussion

The described method for tidal current calculation may be useful for other investigators. For instance: our observations of the current orientating habits of virtually all species of bottom and near-bottom dwelling fish may provide the basis for an interesting catchability experiment when trawling with or against the current. Several other uses of this information come to mind for our investigation alone.

There are some qualifications however that need to be understood prior to using this method. The first is that it is unlikely that any particular experiment will be performed at the exact site of one of the historical current meter locations. Our dive site #1 was approximately 20 kilometers from station PS used in our calculations. This problem can be approached from two avenues. One, choose several current meter locations around your proposed station and compare them in terms of water depth and bottom topography

choosing the location that compares most favorably. The second option is to use the extrapolations made by Moody et al. (1984) found in their Atlas. Generally speaking, for current direction, the water on Georges Bank moves as a whole with the exception of the channel areas and shoal central Bank. This reduces the problem from the current standpoint somewhat.

Another factor to consider is that of current speed. Many of the current meter sites do not have near bottom instruments. Moody roughly estimates bottom currents (lower 2-3 m) at 50% of mid-water velocities. During our studies the bottom current (95 m) was approximately 45% lower than that predicted by the 44 m instrument used in the calculations. However, for our purposes the amplitude was not nearly as important as direction.

In summary, the ability to predict tidal current direction with great accuracy ( $\pm 5^\circ$ ) and to a lesser degree speed, was a great aid to our successful submersible operations. Since the publication of the Tidal Atlas, these calculations can be readily performed covering a large area of the Northwest Atlantic and should be of use to many different field experiments.

## Literature Cited

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- Schureman, P. 1941. Manual of harmonic analysis and prediction of tides: U.S. Department of Commerce, Coast and Geodetic Survey, Special Publication No. 98, 317 p.

## Acknowledgements

The methods for tidal current calculation come directly from Appendix II of Moody et al. (1984). The author wishes to thank John Moody for his help in learning the technique and cross-checking our original calculations for their accuracy.

Table I. From Schureman (1941)  
Lunar node correction factor (f)

	1985	1986	1987	1988
M2, N2	0.974	0.967	0.964	0.964

Table II. Tidal Frequencies and Periods

Constituent	deg/hr	T(hours)
M2	29.984	12.421
N2	28.440	12.658
S2	30.000	12.000

(10)

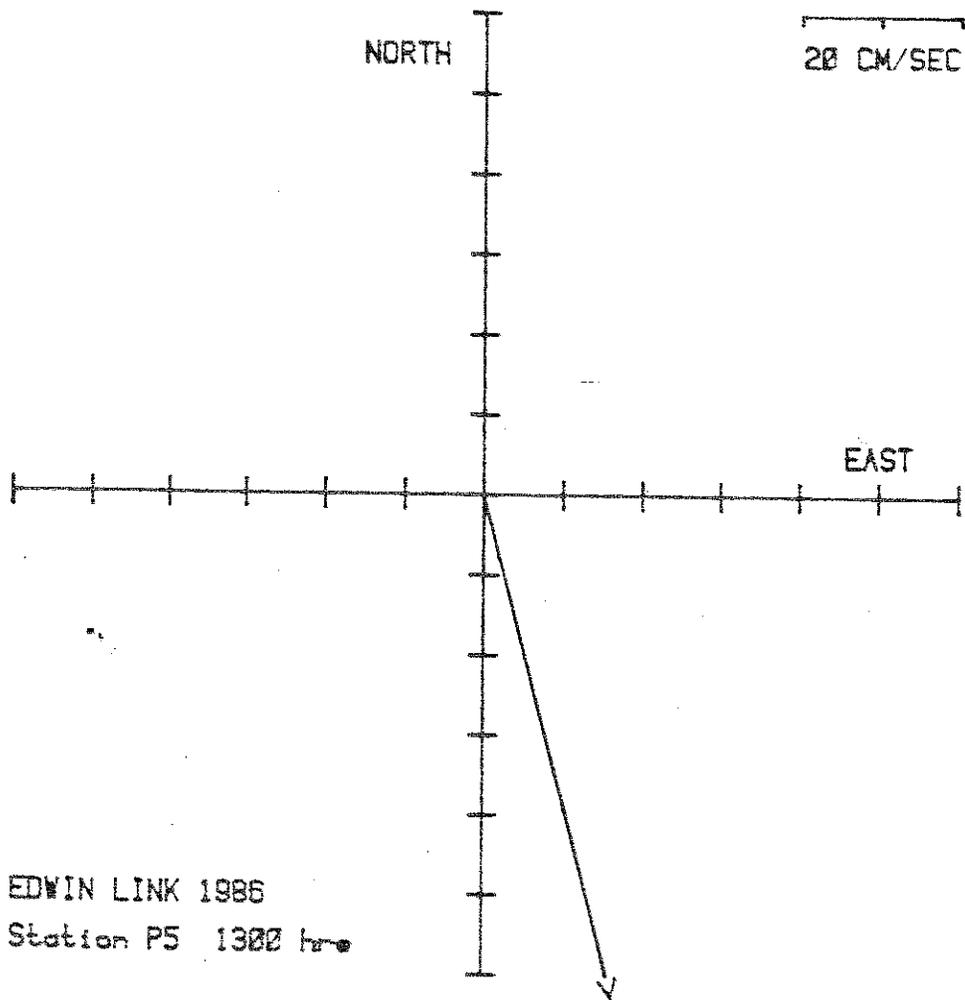


FIGURE 1. Amplitude and direction of tidal current at 1300 hrs, August 4, 1986 at location P5.