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Moored Measurements of Bottom Pressure and Currents for Calibrating and Interpreting DST Data on the Grand Bank

by

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Abstract

As an integrated part of a renewed data storage tagging (DST) program for the yellowtail flounder on the Grand Bank, we deployed an oceanographic mooring from November 2003 to November 2004. Harmonic analysis was carried out on bottom pressure gauge, DST pressure, and current meter data from the mooring. The observational results provide further validation of Han's (2000) tidal model in the study region. The present study indicates that moored DST sensors are capable of accurately capturing the semi-diurnal and diurnal tidal response in spite of their low accuracy. Temperature data indicate substantial change in the bottom temperature, most strikingly, in response to the migration of the cold intermediate layer.

Introduction

Recent data storage tagging (DST) data have indicated that adult yellowtail flounder over the Grand Bank of Newfoundland undergo distinct off-bottom vertical migrations (Walsh and Morgan, 2004). Studies on the plaice, *Pleuronectes platessa*, in the North Sea revealed an interesting migration mechanism to and from spawning grounds by so called selective tidal stream transport (see for example Hunter *et al*., 2004). A preliminary examination of the potential relationship between the tide and off-bottom migration over the Grand Bank suggest the off-bottom excursion of yellowtail flounder during the nighttime be associated with high tides (Walsh and Morgan, 2004).

To further explore this interesting migration behavior and the role that tides may have on yellowtail flounder behaviour we deployed an oceanographic mooring on the Grand Bank for the period from November 2003 to November 2004. Our main objectives were to measure tidal current variability to further validate Han's (2000) tidal model in the study region and to evaluate the accuracy of newly acquired DST sensors in measuring tides, temperatures and depths.

Methodology

Between 20 November 2003 and 21 November 2004 a bottom anchored oceanographic mooring was deployed on the central Grand Bank (Fig. 1). It is located geographically at 45°30.1024'N and 49°59.9378'W, with a sounding depth of 65 m. The mooring includes a current meter (Aanderaa RCM-7) and a bottom pressure gauge with temperature and salinity sensors (WLR 7). Six DST sensors were also installed, 4 programmed to measure depth and temperature for 32 minutes (~ 12 month memory capacity) and 2 programmed for 16 minutes (~6 months memory capacity) (see Walsh *et al*., 2006 for details on DST specifications) . Figure 2 shows the schematic mooring design. From the appearance of the recovered instrument, it is possible that bio-fouling occurred sometime after the deployment.

The nominal accuracy is 0.01% for the bottom pressure gauge and 0.4% for the DST sensors. For all pressure data series, we removed their respective means and then converted pressure anomalies to sea level anomalies. Both the sea level anomalies and the current meter data are subject to a harmonic analysis to retrieve harmonic constants.

Results and Discussion

Sea Level

We carried out tidal analysis of the bottom pressure gauge data (Fig. 3). The tidal signal accounts for dominant variability in the sea level. Major semi-diurnal and diurnal constituents and other selected harmonics are shown in Table 1. The sea level constructed from the major semi-diurnal and diurnal constituents compared well with Han's (2000) tidal model results (Fig. 4), confirming once again the accuracy of the model.

Tidal analysis was also conducted for the pressure data from the 6 DST records (Fig. 5). There is good agreement of tidal parameters between the bottom pressure gauge and DST observations (Fig. 6). It's clear that the moored DST sensor is able to capture major semi-diurnal and diurnal tidal variability accurately, in spite of its lower accuracy.

From the semi-annual and annual harmonics one can construct the seasonal change for the sea level. The sea level was higher in summer and fall and lower in winter and spring. The result agrees well with satellite measurements and steric height (Han, 2006).

However, the analysis indicates that the annual and semi-annual cycles from the DST sensors are significantly different from those of the bottom pressure gauge data. The residuals of the DST data have much larger variability that is physically unplausible.

Currents

We carried out the harmonic analysis of the current meter data (Fig. 6). The harmonic constants for major tidal constituents are shown in Table 2. The tidal currents constructed from Han's (2000) model currents are in approximate agreement with the observations. A comparison for a selected period is given in Fig. 3.

The mean current for the study period has a speed of 3 cm/s, dominated by the northward flow (Table 2). The annual cycle is weak relative to the tidal current variability.

Temperature and Salinity

The temperature variations from CTD and DST #4 (and the other five DST sensors) agreed very well (Fig. 7). During the first 8 months, temperature varied between 0.5 to 2.5°C. Afterwards the temperature showed a general decreasing trend until a rebound occurred in October 2004. The lowest temperature was -0.5°C. This episodic change is probably associated with the movement of the cold intermediate layer (CIL). The CIL is characterised by temperature of <0°C and salinity of 32-33 PSU. The CIL may have important implications for fish migration and distribution on the Grand Bank.

The salinity on average was about 33 PSU during the first six months, with intra-seasonal variations of less than 1 PSU. The pattern is consistent with the general understanding of the bottom salinity in this region. However, the salinity decreased continuously and drastically afterwards, to about 28 PSU (not shown), which is not physically plausible for this region, and probably associated with bio-fouling.

Summary

The moored DST pressure sensors are able to accurately capture semidiurnal and diurnal tidal height variations and temperature. Nevertheless, the depth measurement is less accurate. The bottom pressure gauge data and current meter data lend a further support to the Han's (2000) tidal model in the Grand Bank region. The mooring data and tidal model results are being integrated into fish tagging data to explore potential impacts of tidal variability on the off-bottom migration of the yellowtail flounder on the Grand Bank (Walsh *et al*., 2006).

References

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Table 1. Harmonic constants derived from the bottom pressure data.

Constituent	Period (d)	Amplitude (cm)	Phase (^{o})
M_2	0.52	29.4	334
S_2	0.5	11.2	11
N_2	0.53	6.2	319
K_1	1.0	5.7	158
O_1	1.1	4.1	149
M_f	13.7	1.0	264
M_m	27.6	1.1	268
S_{sa}	182.6	3.7	23
S_a	365.2	6.8	170

Table 2. Harmonic constants derived from the current meter data.

Constituent	Eastward Component (U)		Northward Component (V)	
	Amplitude (cm/s)	Phase (^{o})	Amplitude (cm/s)	Phase (^{o})
M_2	6.8	23	6.7	260
S_2	2.1	44	2.4	280
N_2	1.7	8	1.6	249
K_1	0.1	350	0.2	113
O_1	0.6	273	0.5	160
S_a	0.6	204	1.0	19
Mean	-0.3	0	2.9	0

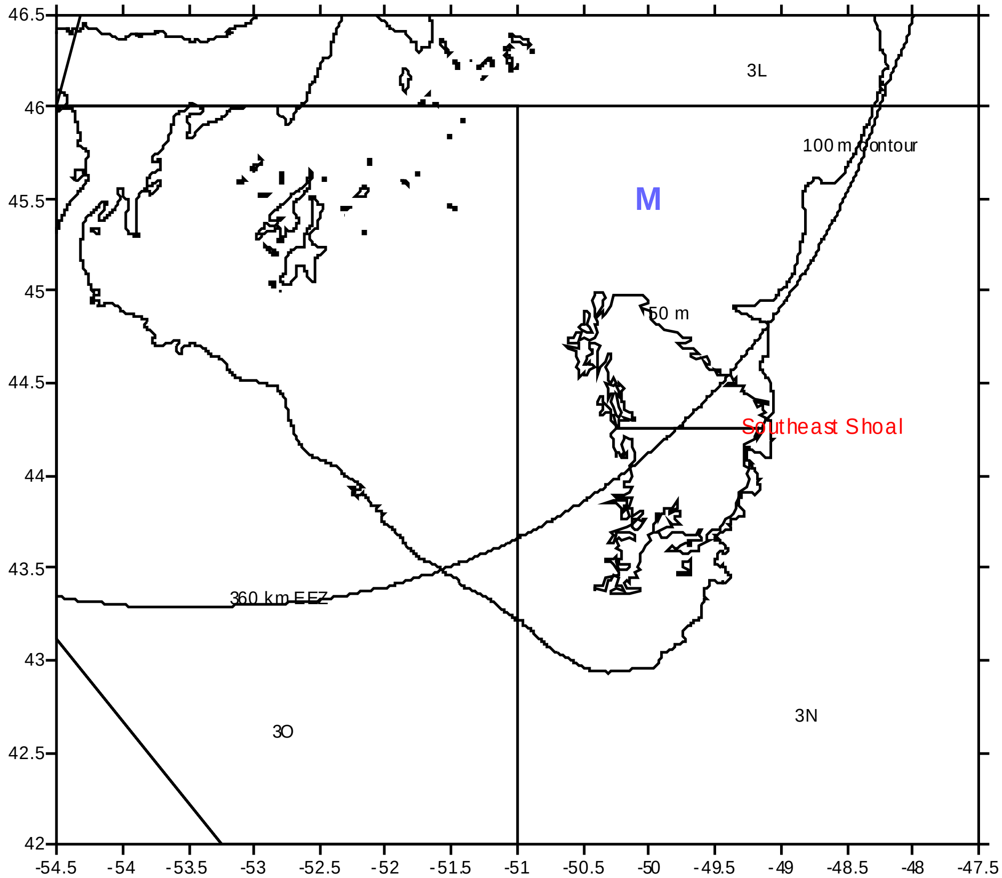

Fig. 1. Map showing the Grand Bank of Newfoundland. The mooring site is depicted as a blue letter "M".

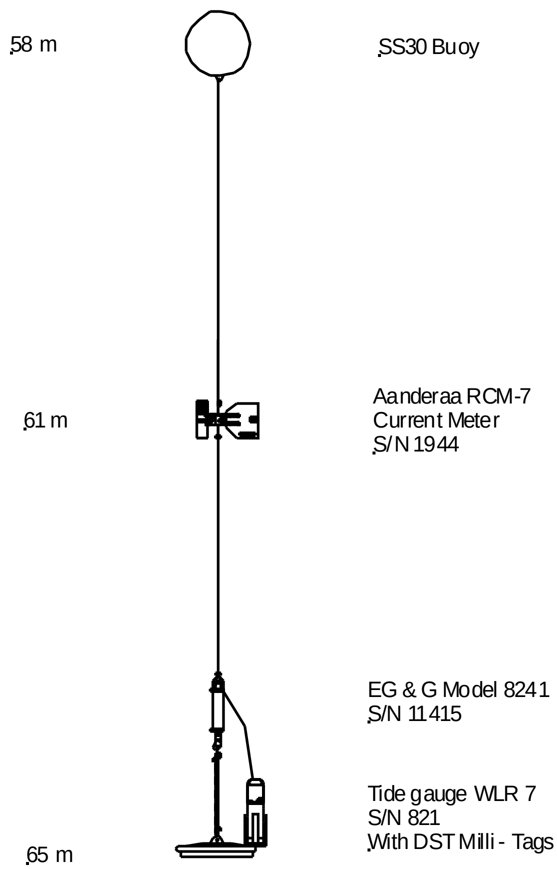

Fig. 2. Schematic diagram of the mooring.

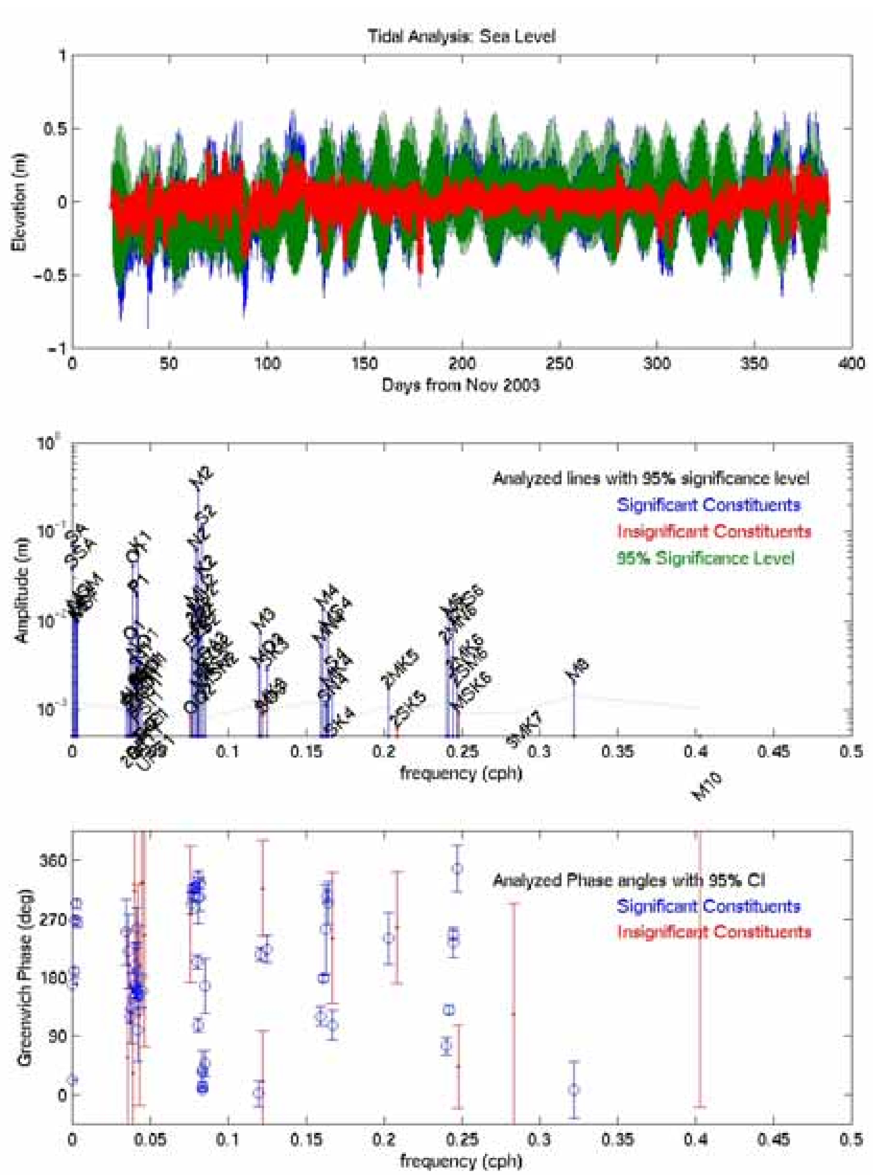

Fig. 3. Bottom pressure data and analysed results: (a) Time series, (b) Amplitude of harmonics, and (c) Phase of harmonics.

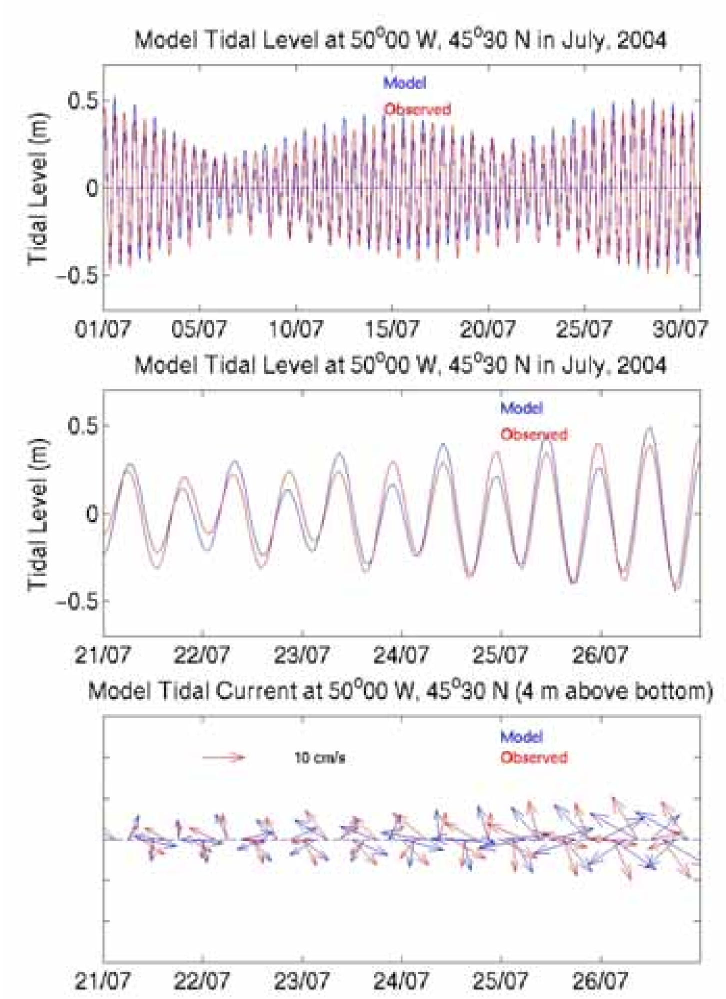

Fig. 4. Comparison of Han's (2000) model tidal height and currents with moored measurements for selected time periods.

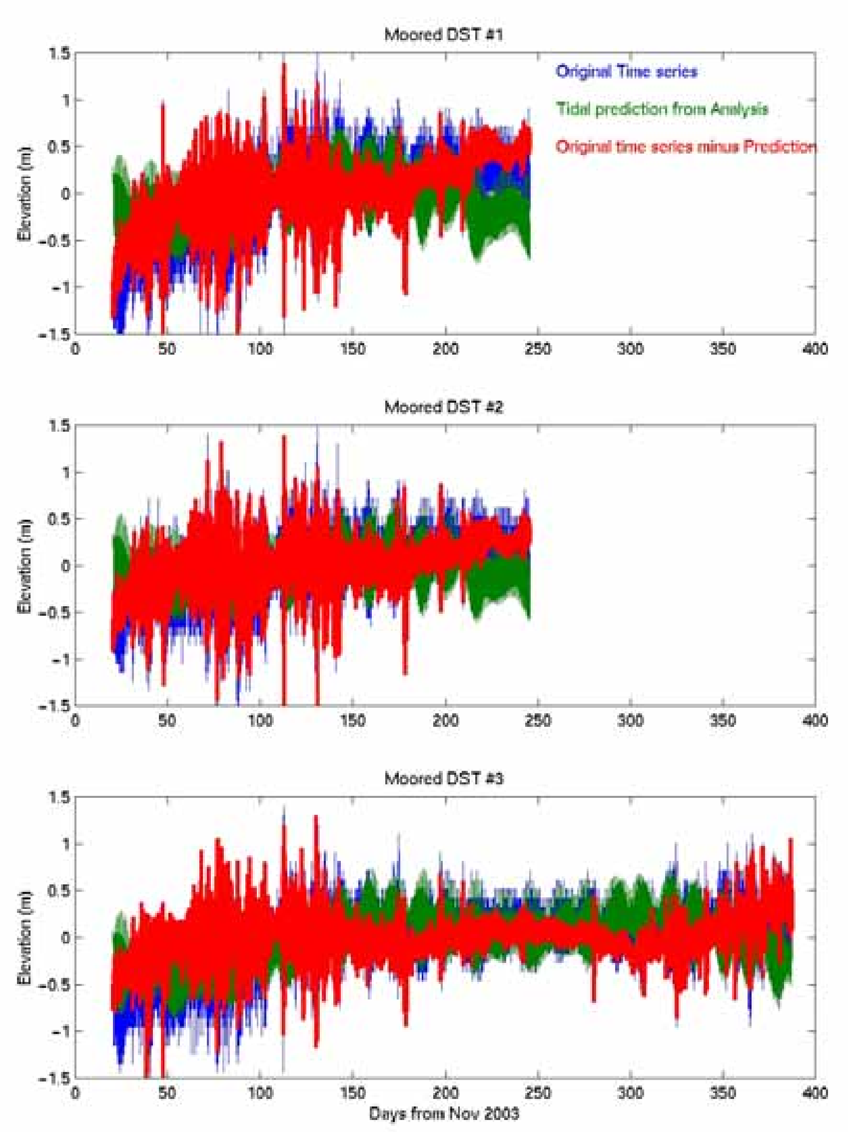

Fig. 5. Sea level variations based on the six DST sensors.

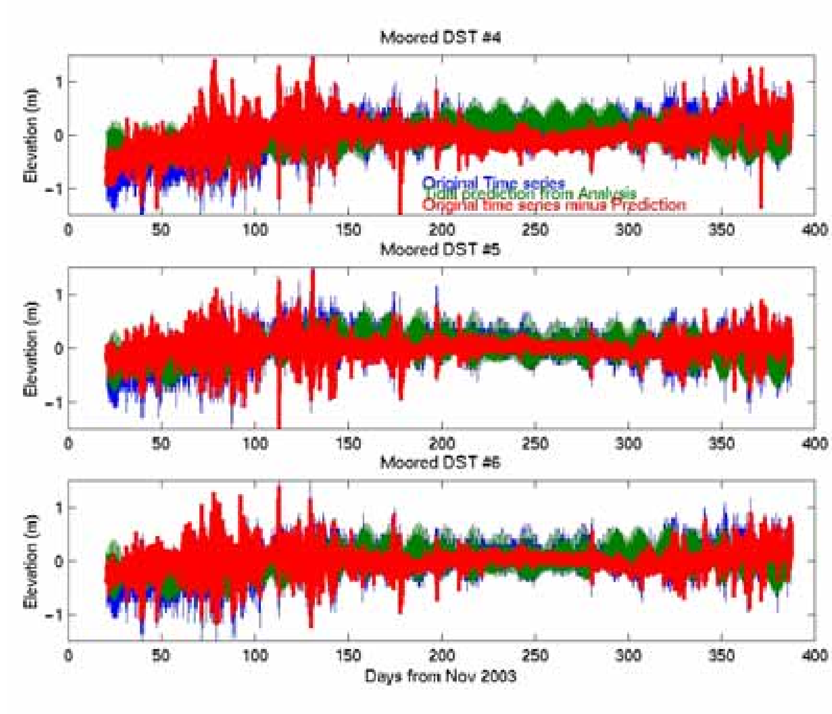

Fig. 5. (continued).

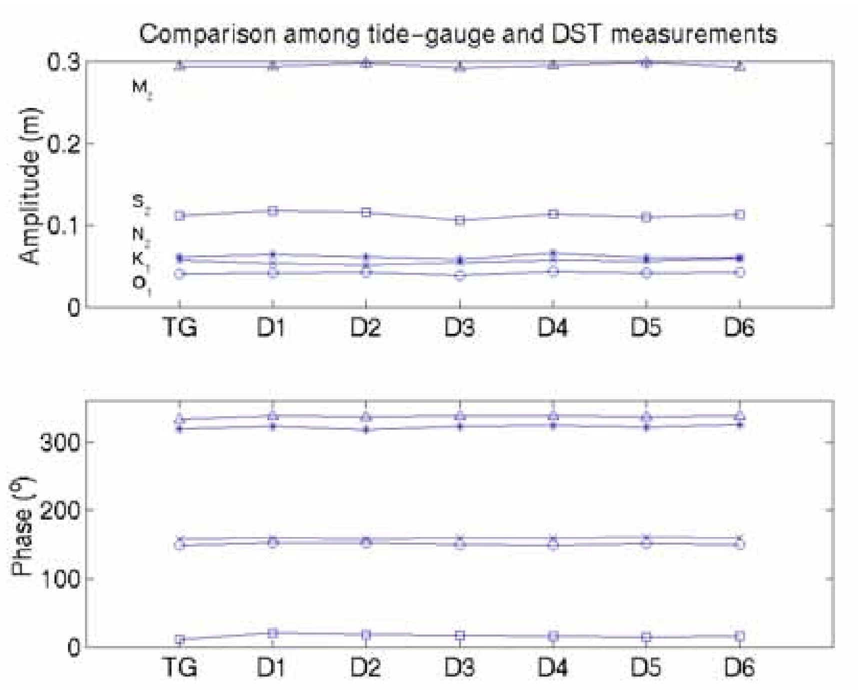

Fig. 6. Amplitude and phases for five major semi-diurnal and diurnal tidal constituents from the bottom pressure gauge and 6 DST sensors.

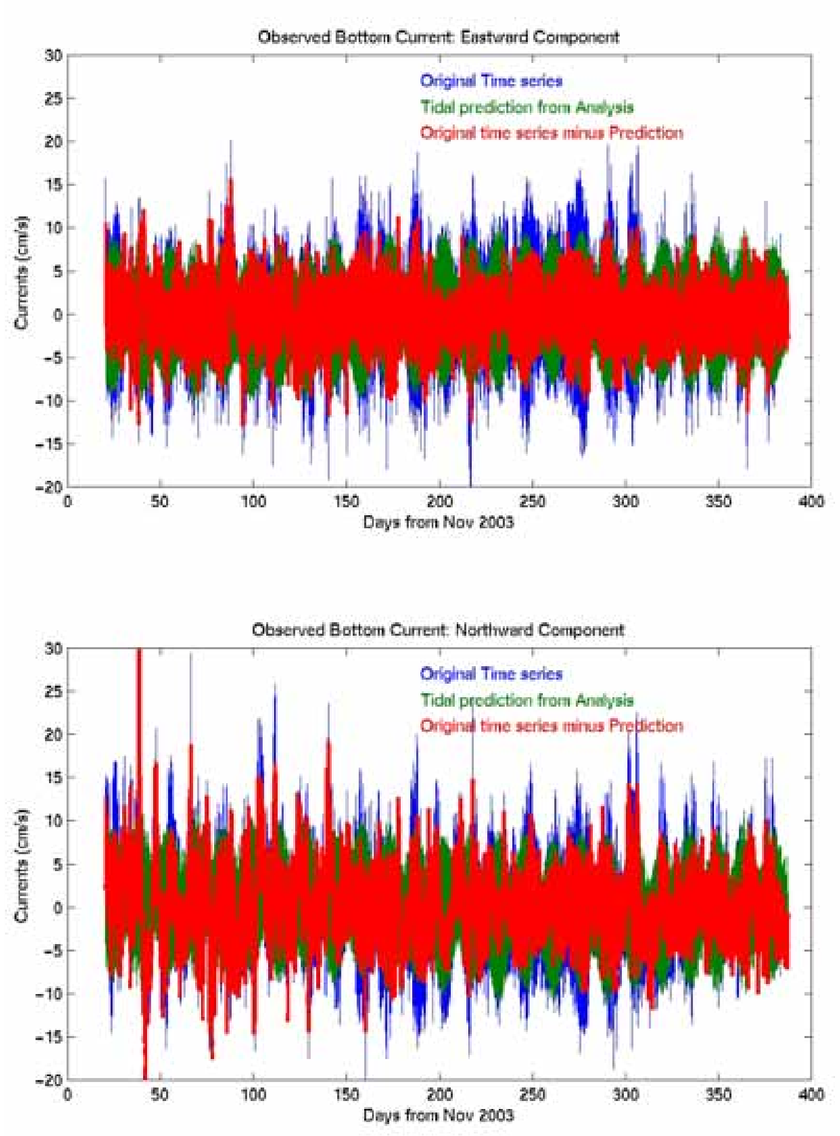

Fig. 7. Current variations based on the current meter data.

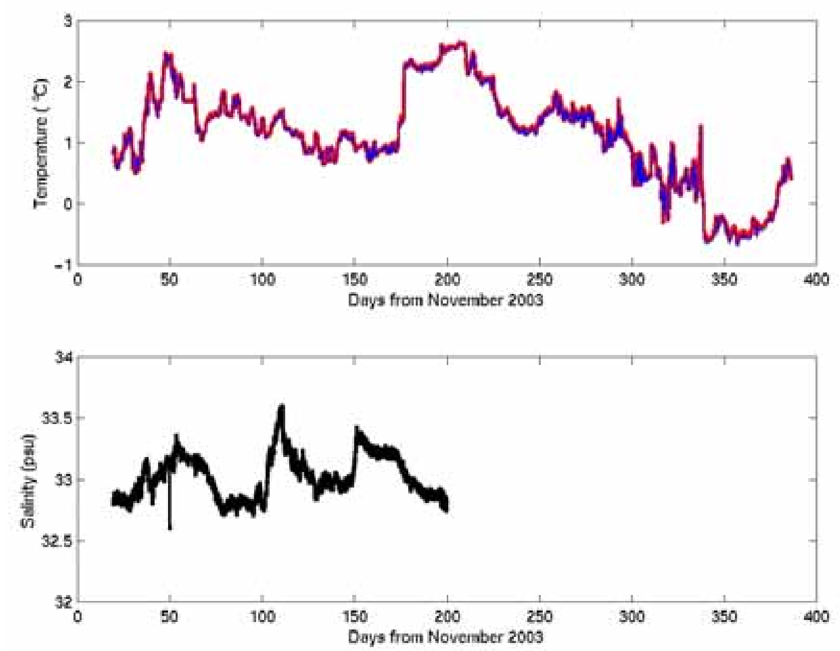

Fig. 8. Temperature (upper panel, WLR in red and DST #4 in blue) and salinity (lower panel) data. The salinity data after Day 200 were removed.