NOTES AND CORRESPONDENCE

Estimating Mooring Motion when the Pressure Sensors Fail: A Method Employing Inverted Echo Sounders

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ABSTRACT

In the presence of a strong current, such as the Gulf Stream or the North Atlantic Current, current meter moorings are known to ''blow over'' due to drag from the moving water. This dipping of the current meters, which has been documented to exceed 500 m in some cases, can significantly affect estimates of fluxes on level surfaces. Pressure measurements made by sensors collocated along the mooring near each current meter are commonly used to correct for this mooring motion. Data from a current meter mooring near 42°N, 45°W are used to demonstrate that, in cases where there is a failure of the pressure sensors, measurements from an inverted echo sounder near the current meter mooring can be combined with the mooring temperature records and historical hydrography to produce ''synthetic'' pressure records for current meters within the main thermocline depth range. Pressures at other current meters on the mooring can then be determined using mooring design parameters. This technique allows corrections for mooring motion when they would otherwise be impossible due to the loss of the directly measured pressure records. Comparison to directly measured pressures in the main thermocline from a mooring near the North Atlantic Current demonstrates that this technique can determine synthetic pressure records to within a root-mean-square difference of about 46 dbar for an instrument with observed mooring motion related pressure dips of 200–500 dbar. The technique is also applied to a number of other current meters in the North Atlantic Current region as well as instruments that were moored in the Subantarctic Front near 143°E to demonstrate where the technique will and will not work.

1. Introduction

A well-known problem in the use of a moored current meter with subsurface flotation, that is, a mooring without a surface expression, in regions of high horizontal velocities is the ''blow over'' of the mooring. Usually referred to as mooring motion, in the Gulf Stream there are documented cases where the shallowest current meter on a mooring, nominally at 400–500 m, has dipped so much that the current meter was actually at a level of 900–1100 m (Hogg 1986; Hendry 1988; Shay et al. 1995). This mooring motion complicates the calculation of momentum and heat fluxes at depth levels using current meter measurements, resulting in values that could be different by as much as an order of magnitude from flux estimates determined using measurements corrected for mooring motion (Hogg 1991).

A number of methods have been developed for correcting moored temperature and velocity measurements for mooring motion, but the most commonly used methods are all variations on the methods developed by Hogg (1986, 1991). A basic description of these methods follows; first these methods require the assumption of a canonical vertical profile of temperature and velocity for the region in question, frequently a hyperbolic tangent or something similar. Once these profiles are determined, the pressure and temperature measurements from the mooring are used to determine the vertical offset of the canonical profiles (to account for vertical motion of the main thermocline). Finally, once the canonical profiles have been adjusted to account for thermocline location, the temperature and velocity at a fixed level for each of the current meters can be determined. There are some variations of this method, but this basic description is adequate for the purposes of this paper.

One critical requirement of the Hogg (1986, 1991) method is the possession of temperature and pressure measurements both above and below the main thermocline. This is necessary in order to determine the depth at which the main thermocline in the canonical profile should be placed. Unfortunately, pressure measurements in the ocean are sometimes difficult, with pressure sensors being subject to large drifts (Watts and

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Kontoyiannis 1990), and instrument failure is always a possibility with any ocean measuring system. In a recent experiment in the Southern Ocean the failure rate for the pressure sensors was about 17%, and during an experiment in the Gulf Stream in the late 1980s where a large number of deep pressure sensors were deployed about 15% of the instruments failed completely while another 25% of the instruments suffered from large drifts (Watts and Kontoyiannis 1990). The failure of the pressure sensors on the Southern Ocean mooring lead us to search for a method of simulating the pressure records needed for mooring motion correction, resulting in the method presented here.

Failure of the pressure sensors makes mooring motion correction using the Hogg (1986, 1991) method impossible. However, in situations where an inverted echo sounder (IES) is located near the mooring (or a coherent array of IESs surrounds the mooring) and where the temperature sensors on the mooring functioned properly, it is possible to determine ''synthetic'' pressure records to accompany the temperature records. As will be shown later, this method works best in depth layers with large vertical gradients of temperature, such as in the main thermocline; however, by determining the pressure at one of the current meters it is possible to estimate the pressure at other instruments using mooring design parameters. The purpose of this paper is to demonstrate how this method works, and to test it using moored measurements at a site near the North Atlantic Current (NAC) near 42°N, 45°W where the moored pressure sensors worked properly and where an IES was located within about 1 km of the current meter mooring. Tests using an additional mooring near the NAC as well as two moorings near the Subantarctic Front (SAF) will also be presented to illustrate some of the limitations of the method.

2. Data

From August 1993 until April–June 1995, a line of moored current meters and IESs was deployed across the North Atlantic Current near 42°N, 45°W as part of a collaborative study involving the University of Rhode Island and the Bedford Institute of Oceanography in Halifax, Nova Scotia (Meinen et al. 2000; Meinen and Watts 2000; Meinen 2001). The current meter mooring designated as site 8 in that study is the principal mooring employed in this paper. Site 8 was located just offshore of the mean position of the NAC (Meinen and Watts 2000). Six current meters on the site 8 mooring returned good temperature and velocity data, but only the upper three (nominal depths of 420, 830, and 1550 m) had good pressure records. An IES was also deployed at site 8 within about 1 km of the current meter mooring. All current meter and IES data were filtered using a 40-h second-order Butterworth filter both forward and backward to remove high-frequency variability.

In addition to the data from site 8 near the NAC, there was another current meter mooring, at site 4 along the NAC line, which had an IES nearby. Site 4 was inshore of the NAC and data from that site will be used to illustrate some of the limitations of the technique being presented here. Also, in an experiment in the Southern Ocean south of Australia near 51°S, two moorings with nearby IESs were located within an array of current meters, horizontal electrometers, and IESs during 1995–97 as part of the Sub-Antarctic Flux and Dynamics Experiment (SAFDE; Luther et al. 1997). Data from the shallowest current meters on each of these two moorings (nominal depth 300 m) will also be used to illustrate the limitations of the technique being presented here.

Finally, in order to interpret the IES measurements in terms that are useful for developing synthetic pressure records, it is necessary to have a collection of hydrographic data from the region of interest. This hydrography is used to create a ''gravest empirical mode'' (GEM) description of the variance in the region of interest, and the resulting GEM fields are used in concert with the IES measurements in a manner that will be described shortly. The GEM fields for the NAC region were developed and are described in Meinen and Watts (2000), while the GEM fields for the SAFDE region are described in Watts et al. (2001).

3. Methods

Meinen and Watts (2000) developed the GEM method as a technique for extracting additional information from the acoustic travel time measurements of the IES. They demonstrated, for example, that in the western Newfoundland Basin there was sufficient historical hydrography to develop a single lookup table of temperature as a function of both pressure and the simulated acoustic round-trip travel time between the surface and 2000 dbar (τ_{2000}). The travel time was simulated using the hydrographic temperature, salinity, and pressure measurements along with the empirical equation for oceanic sound speed (Del Grosso 1974; Meinen and Watts 1997). Furthermore, they demonstrated that this lookup table captured greater than 95% of the oceanic temperature variability throughout the main thermocline layer, suggesting that an independent measurement of τ_{2000} can be combined with the GEM lookup table to accurately predict the concurrent temperature profile. GEM lookup tables have also been developed for the specific volume anomaly (Meinen and Watts 2000) and salinity (Watts et al. 2001), in addition to temperature, using similar methods; however, it is the temperature GEM which relates to the problem at hand. Because linear empirical relationships can be developed relating τ_{2000} to τ at any other pressure level below the main thermocline (Meinen and Watts 1998), the IES measurements of τ at the seafloor can be combined with the GEM lookup table to provide an estimate of the temperature profile above the IES.

The determination of synthetic pressure records takes

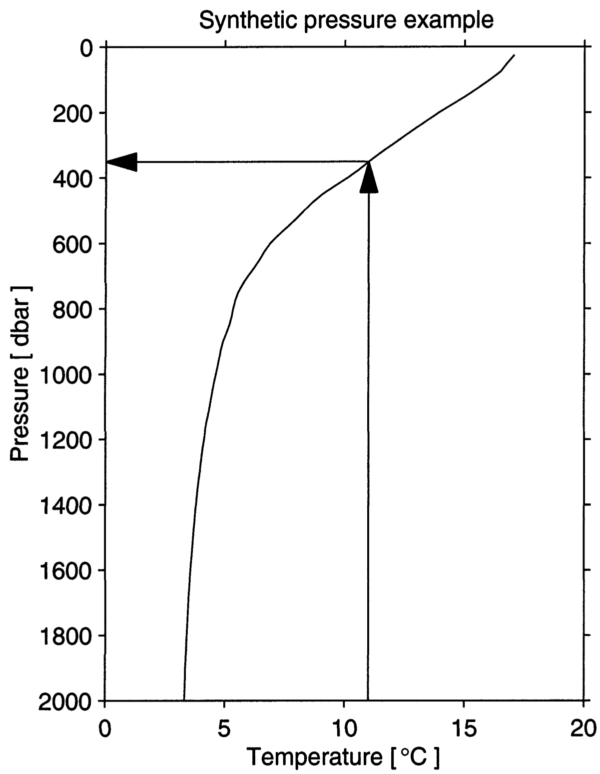

FIG. 1. Example of how synthetic pressure is determined. The solid line denotes the temperature profile predicted by the GEM temperature field for a travel time of 2.6485 in the NAC. If the coincident temperature measured by a current meter is 11°C, illustrated by the vertical arrow, then the synthetic pressure estimated by the technique presented here would be 350.5 dbar, illustrated by the horizontal arrow.

advantage of the predicted temperature profiles from the IES+GEM technique in a different manner. By combining the temperature profile with the temperature measured at any of the current meters on a mooring, an estimate of the pressure can be obtained if the IES + GEM temperature profile is a monotonic function of pressure. One simply determines the pressure at which the current-meter-measured temperature occurs. For example, Fig. 1 shows the temperature profile predicted by the GEM field for a measured travel time of $\tau = 2.6485$ in the NAC. If the current meter at the same time measured a temperature of 11°C, then the estimated pressure is 350.5 dbar. This can be done for each point in time where there is both a measured temperature from a current meter and a temperature profile estimated from the IES and GEM data. By processing each temperature record on a mooring in this manner, a synthetic pressure record can be determined for each current meter.

Minor temperature variations resulting from small-scale features might cause the synthetic pressure to fluctuate above or below the actual pressure level of the instrument while these small-scale events would probably not result in any appreciable mooring motion. Assuming the small-scale features are linear additions on top of the mesoscale signals of interest, and assuming that the mooring is in its ‘‘resting’’ shape over 50% of the time, eliminating all synthetic pressure values less than the median eliminates about half of the small-scale noise and results in a fairly accurate estimate for the ‘‘resting’’ pressure at that current meter level. The median is used because, unlike the mean, it should not be strongly affected by the large mooring motion events. The choice to use the median, however, depends upon how often it is expected that the mooring is nearly vertical in its resting shape. If instead the mooring is blown over more than 50% of the time series, using the median to estimate the resting depth of the current meter results in an overestimate of the actual resting pressure. If other pressure measurements are available from nearby moorings, or from previous moorings at the same location, then those pressure records can be studied to determine what sort of cutoff should be used. For the comparisons shown in the remainder of this paper the median was used as the cutoff. The NAC and SAFDE moored pressure records, which were blown over by more than 40 dbar for 45% and 31% of the respective time series, had median synthetic pressures within 5–30 dbar of the resting measured pressures.

4. Results

Comparison between the synthetic pressure records and the actual measured pressure records at site 8 near the NAC indicates good agreement for the current meter located in the thermocline depths (nominal depth 830 dbar) and poorer agreement at the locations above and below the thermocline (Fig. 2). The root-mean-square (rms) difference between the measured and synthetic pressure records was 75, 46, and 50 dbar for the instruments at nominal depths of 420, 830, and 1550 m, respectively. The correlation coefficients between the pairs of measured and synthetic pressure records were 0.38, 0.73, and 0.66, respectively. Based on these statistics it is evident that the best agreement between the measured and synthetic pressure records occurs for the instrument at 830 m, with the 1550-m instrument providing a close second-best and the 420-m instrument demonstrating the worst comparison. The method was also tested on three additional moorings. The results indicate that rms differences between the measured and synthetic pressures, as well as the correlation coefficients between the records, vary significantly from site to site and from depth to depth (Table 1). At NAC site 4, which was inshore of the NAC during most of the 2-yr time series and which had pressure sensors at several levels (Meinen and Watts 2000), the agreement between measured and synthetic pressure records is generally poor. At the SAFDE moorings, which were near to the strongest flows along the SAF and which had pressure sensors only at the shallowest current meter level on each mooring, the agreement was fairly good

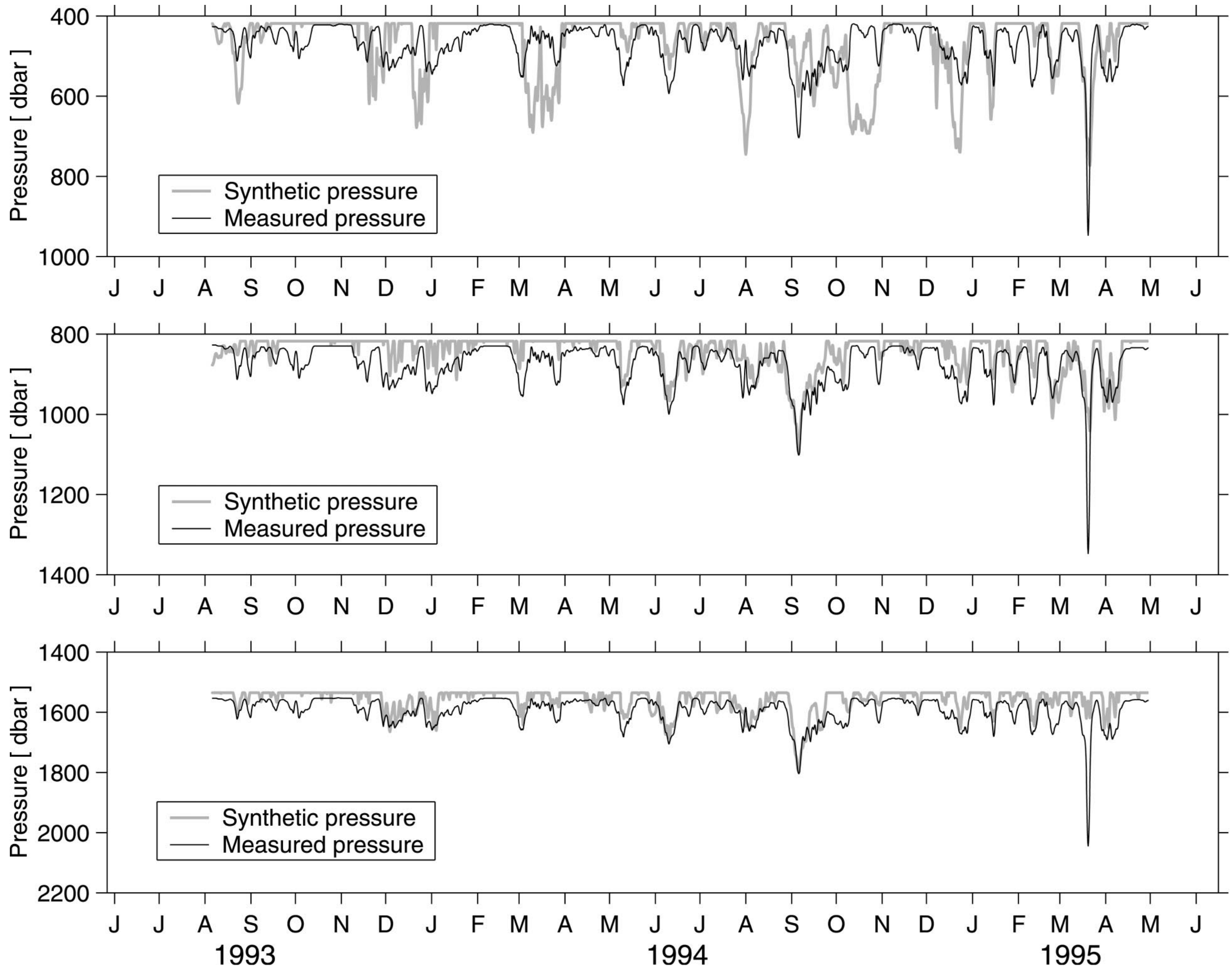

FIG. 2. Comparison of actual measured pressure records (thin black lines) and synthetic pressure records (thick gray lines) at site 8 near the NAC. (top) Comparison for the instrument near 420 m, (middle) comparison for the 830-m instrument, and (bottom) comparison for the 1550-m instrument.

at the mooring denoted as site S but the agreement was poor at site N.

To understand why this technique works fairly well at the 830-m instrument at NAC site 8 but not as well at the 420- and 1550 m levels, consider the vertical structure of the temperature field at this location. Figure 3 presents the mean vertical structure at site 8 over the 2-yr experiment as estimated using the IES data and the GEM field. The minimum pressure levels from the moored pressure sensors are also indicated. At any given time the actual temperature profile would look somewhat different from the mean, with the thermocline moving up and down as the NAC approached and moved past the mooring, as well as changes that could occur due to other processes. Nevertheless, based on the mean temperature profile it is evident that at the level of the 830-m instrument the vertical temperature gradient is larger than it is at the other two instruments. This indicates that at this depth range a small change in temperature corresponds to a small change in pressure, whereas at the other levels where the vertical temperature gradient is weak, a minor change in temperature corresponds to a relatively larger change in pressure. Similar arguments can be made for the other moorings with poor comparisons between measured and synthetic

TABLE 1. Comparison of measured and synthetic pressure records. Std dev is of the measured pressure; Rms difference between measured and synthetic records.

Mooring name	Measured pressure Min	Std dev	Max−min	Rms difference	Correlation coefficient
NAC 4	380	29	490	102	+0.12
	790	28	479	132	+0.24
	1510	26	441	232	+0.14
	2530	15	247	73	+0.16
NAC 8	420	52	527	75	+0.38
	830	51	519	46	+0.73
	1550	46	493	50	+0.66
SAF N	260	67	280	120	+0.27
SAF S	340	62	360	44	+0.71

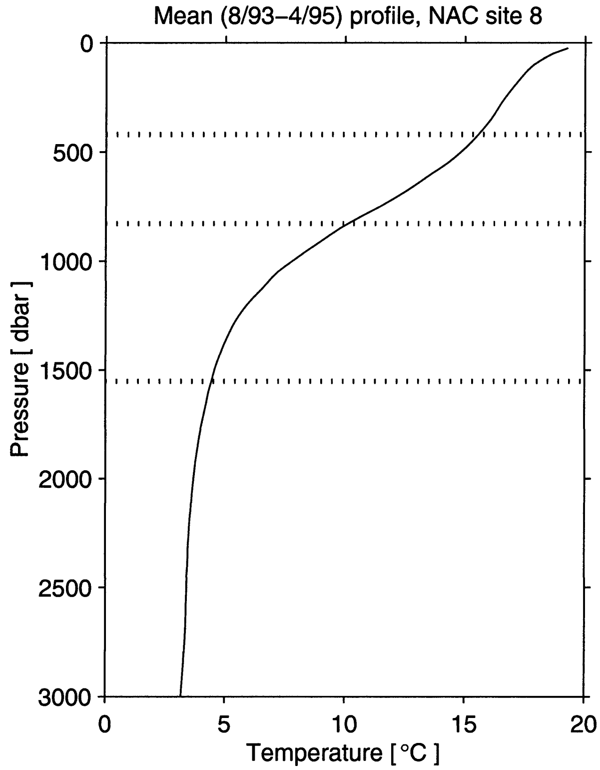

FIG. 3. Mean temperature profile at site 8 as estimated using the IES τ measurements and the temperature GEM field. Minimum measured pressures from the three current meters with pressure sensors on the current meter mooring at site 8 are denoted by horizontal dotted lines.

pressures; all but the shallowest current meter at NAC site 4 were located at levels where there is a relatively weak vertical gradient in temperature. To quantify this result, the time-mean vertical gradient of temperature observed at each of the current meter levels was plotted against the calculated correlation coefficient between the measured and simulated pressure (Fig. 4) for all of the moorings. There is a statistically significant trend (95% confidence level) indicating that the method works better where the vertical gradient in temperature is larger. The correlation obtained using the data from the shallowest current meter on NAC mooring 4 was not used in the linear fit; as will be discussed later, the lack of correlation at that site results from another error source.

To understand the physics behind this relationship, consider that the measured temperatures from the current meters represent variations not only due to the meandering of the NAC but also due to small-scale processes occurring in the region. These small-scale processes, however, are not going to be observed by the GEM technique because it observes only the larger-scale features (Meinen and Watts 2000; Watts et al. 2001). As a result, the minor changes in temperature induced by small-scale features are going to be misinterpreted by the synthetic pressure technique as larger-scale variations than those temperature changes truly represent. Where the vertical gradient in temperature is large, such as at the depth of the 830-m instrument on NAC mooring 8, these minor temperature changes will not result in much change in pressure. In depth ranges where the vertical temperature gradient is weak, however, the minor temperature changes induced by small-scale features can result in large variations in the synthetic pressure. This can be illustrated by computing the pressure error that would result from a small-scale temperature fluctuation observed at the current meter (Figs. 5a,b). Assuming a small-scale temperature fluctuation of 0.1°C, the error in the resulting synthetic pressure can range from a few decibars for the 830-m instrument on NAC mooring 8 to over 400 dbar for the 1510-m instrument on NAC mooring 4.

The shallowest current meter at NAC site 4 presents an interesting special case. The current meter was located in the main thermocline (significant vertical gra-

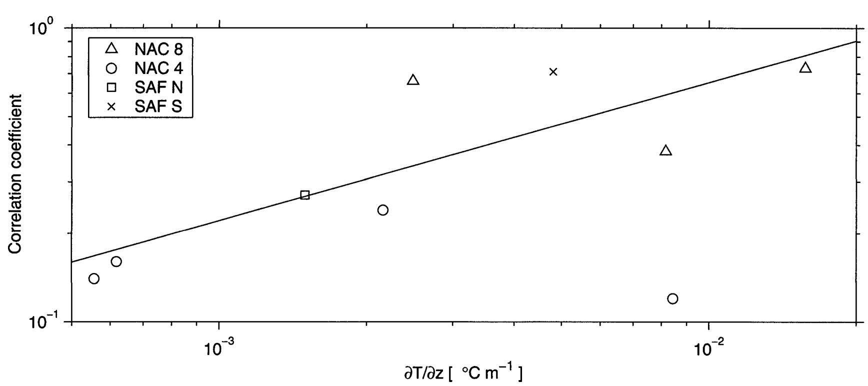

FIG. 4. Correlation coefficient between measured and synthetic pressure as a function of the time-mean vertical gradient of temperature at the ''resting'' pressure of each current meter. Different symbols refer to different moorings as noted in the legend. The sloped line is a least squares fit to the data excluding the shallowest instrument on the NAC 4 mooring (circle at about $\partial T/\partial z = 0.0085$°C m^{-1}), which is discussed in detail in the text. The slope of the line is statistically different from zero at the 95% confidence level.

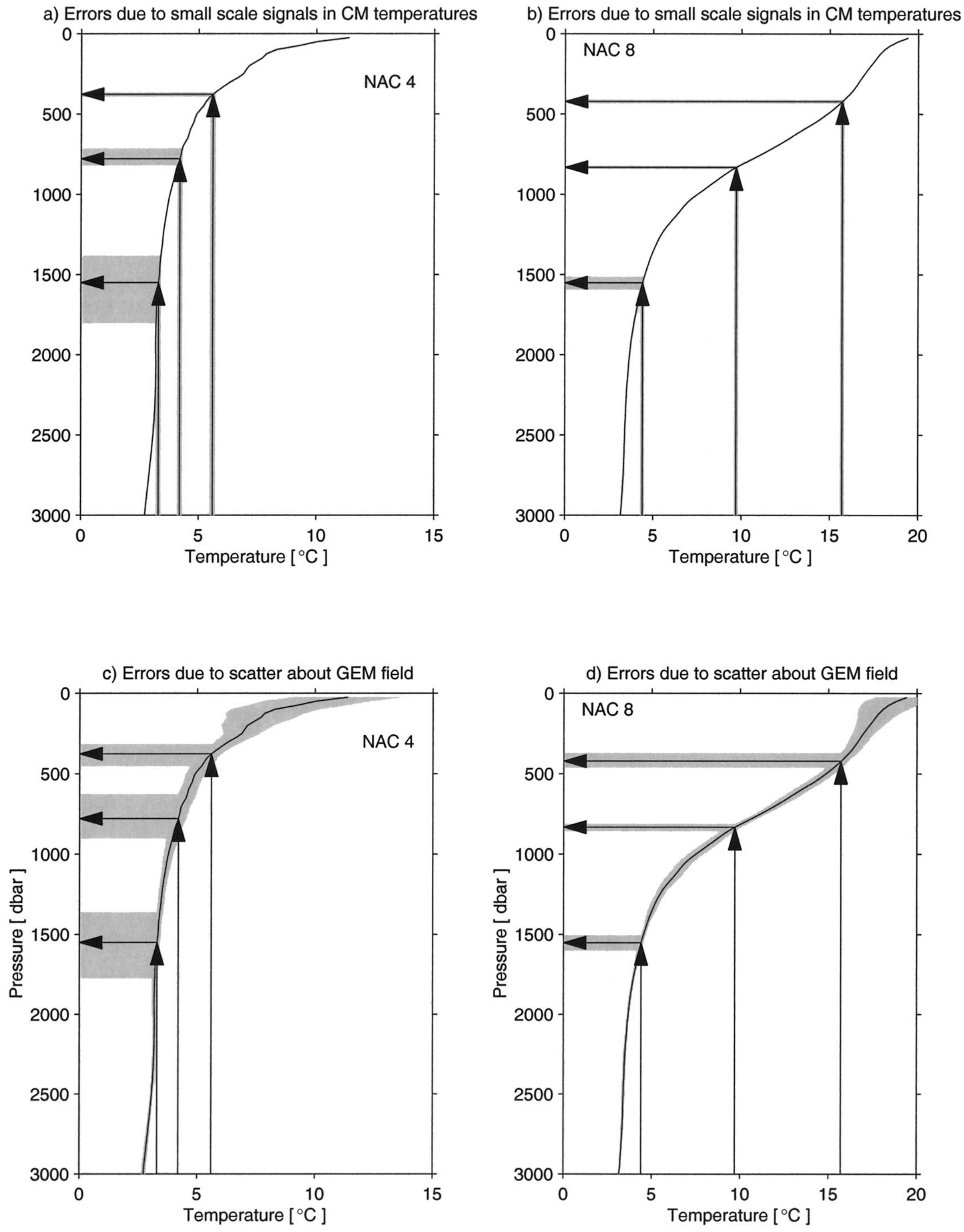

FIG. 5. Illustration of error sources for the synthetic pressure methodology: (a) vertical gray bars represent a possible small-scale temperature signal of 0.1°C observed by a current meter at NAC site 4, while the horizontal gray bars represent the resulting errors in the synthetic pressure; (b) similar to (a) but using time-mean temperature structure for NAC site 8; (c) gray band surrounding the temperature profile shows the time mean of the estimated rms scatter about the GEM profile at NAC site 8, while the horizontal gray bars represent the resulting synthetic pressure errors; and (d) same as in (c) but for NAC site 8.

dient in temperature), and as such the synthetic pressure should compare well with the measured pressure. The statistics in Table 1 indicate, however, that this is not the case. To find the reason for the poor comparison it is necessary to look back at the GEM temperature field determined for the NAC region (see Meinen and Watts 2000, Plate 1). At shallow depths for the values of τ observed by the IES at NAC site 4, the scatter around the GEM field is fairly large in comparison to other ranges of τ. This results from the influence of Labrador Current (LC) water, which at times moves off the continental shelf and into the region near NAC site 4 (Meinen and Watts 2000). This increased scatter indicates that the shallow temperature profiles are less likely to look like the GEM estimated profiles, and thus using the GEM temperature profile in concert with the moored temperature data will not provide a very accurate estimate of pressure. Figures 5c,d illustrate the errors in synthetic pressure that could result from the scatter about the GEM field at NAC sites 4 and 8. There is considerable scatter near the surface, mainly due to seasonal effects that can be modeled and removed (Watts et al. 2001), but the scatter drops off rapidly with depth. Figure 5 clearly indicates that the synthetic pressure method should work better at NAC site 8 than at NAC site 4, which is consistent with the results in Table 1.

The problem at NAC site 4 only occurs for a fairly narrow range of τ and pressure, and the LC–NAC region represents one of the most complicated ocean regions in terms of water masses. Nevertheless this illustrates that there are two requirements in order to be able to use measurements from an IES along with moored temperature sensors to estimate the corresponding pressures. First, a GEM temperature field for the region must be determined and the scatter about that field (caused by intrusions, internal waves, and other higher-mode processes) must be small at the pressures and τ values that occur at the current meter site. Second, the moored temperature record must be at a depth where there is a large vertical gradient in temperature such as the main thermocline.

An important consideration here is that although the synthetic pressure does not compare well to the measured pressures for some of the current meters illustrated above, this does not imply that the technique would not work at all at these mooring sites. Considering the mean temperature at SAFDE site N (not shown), temperature records at levels within 500–700 m would be well within the main thermocline where the largest vertical gradients are observed. So even though the synthetic pressure agreed poorly with the measured pressure at 300 m at SAFDE site N, the technique could still be applied to temperatures measured by deeper current meters at depths of 500–700 m. As was demonstrated at NAC site 8 where the 830-m instrument was within the main thermocline (Figs. 2 and 3), the agreement between synthetic and measured pressure records for midthermocline levels is quite good.

Determining pressure variations for instruments outside the thermocline level

The method presented so far details a technique for creating a synthetic pressure record for a current meter within the main thermocline level. Most current meter moorings for which mooring motion correction is desirable have more than one current meter, and some of these other current meters are generally above or below the main thermocline level. Since the temperature records cannot be used to estimate the pressures at those levels, another method must be used to develop simulated pressure records at these other levels. There are a number of ''mooring design'' computer programs available that allow the user to determine how much mooring motion will occur for various mooring designs and under different oceanic current regimes (e.g., Berteaux and Chhabra 1973; Moller 1976; Mo and Watts 1987). Such programs allow for the determination of whether, under the observed current regime, a mooring is likely to stretch out nearly linearly or take on a more complex catenary shape. With the pressure variations obtained for the midthermocline instrument, along with the mooring line lengths and the predicted shape from the mooring design program, it is possible to determine the variations of pressure at the other current meters along the mooring.

Alternately, if the mooring that has lost its pressure records was deployed in an experiment involving other moorings with pressure sensors, the measurements from those other moorings provide a method for determining the pressure variations at all of the current meters on the problem mooring based on the midthermocline pressure variations. As an example, the measured pressures at NAC site 8 provide insight into how this can be done. First, the mooring design provides an estimate for the resting pressure difference between any two current meters on a mooring based purely on the amount of wire that was put on the mooring between the current meters. When the mooring is not experiencing motion, these values should allow for the determination of the pressure levels of the other instruments based on the synthetic pressure level from the instrument in the midthermocline.

To determine how the variations in the synthetic pressure at the midthermocline level can provide information about the vertical motion of the other instruments, the measured pressure departures from the minimum observed pressure (Δp) by the 830-m instrument at NAC site 8 were compared to the measured Δp at the 420- and 1550-m instruments (Fig. 6). The vertical deflections, or blow over, of the current meters at the 420- and 1550-m levels was almost exactly the same as those for the 830-m level, suggesting a catenary shape for the mooring motion. Because of these nearly 1:1 relationships, the depth variations of the other instruments can be estimated simply by looking at the estimated depth variations at the midthermocline level. While there is

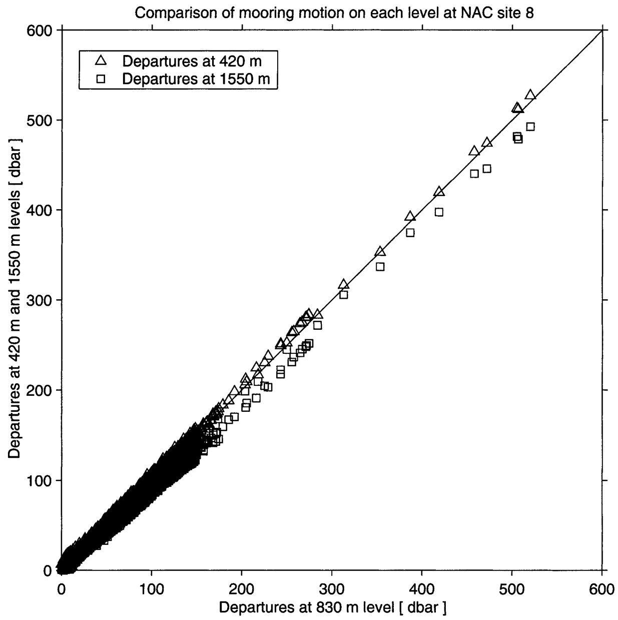

FIG. 6. Comparison of current meter ''blow over'' as measured by the pressure sensors on the mooring at NAC site 8. Departure indicates the difference between the observed daily pressures and the minimum measured pressure for each instrument. Solid diagonal line has a slope of one. Symbols denote comparisons between the departures at the 830-m level and the other levels as noted in the legend.

some scatter about the lines in Fig. 4, the agreement should be good enough for most purposes. Applying the Hogg (1986, 1991) mooring motion technique using these synthetic pressures will certainly result in better estimates of the fluxes than would result from ignoring mooring motion altogether (although the prudent researcher would devise tests simulating the mooring motion in order to determine the possible residual mooring motion biases in estimates of fluxes, etc.). Applying a 1:1 relationship between the variations at 830 m and the variations at 420 and 1550 m considerably improves the comparisons between measured and synthetic pressures (Fig. 7). Comparing the resulting synthetic pressure to the directly measured pressures at 420 m indicates that the standard deviation of the differences between synthetic and measured pressures is reduced from 75 dbar for the directly GEM determined synthetic pressures at 420 m to 36 dbar for the adjusted synthetic pressures determined using the 1:1 slope relationship. Similarly for the pressure comparisons at the 1550-m level, there is a reduction from 50 to 32 dbar.

It is important to note that the relationships in Fig. 6 apply only to the type of mooring deployed during the NAC experiment. Different arrangements of flotation, fairing, and instrumentation could result in different relationships between deflections at various levels. Unless similarly designed moorings were deployed during the same experiment, or have been deployed in the past in a similar environment, simple relationships between deflections at various levels cannot be developed. In those cases the use of a mooring design program will be necessary to determine the mooring line shape as the mooring blows over.

5. Summary and conclusions

In order to facilitate mooring motion correction for a mooring that has suffered the failure of its pressure sensors (as happened during SAFDE), this study has presented a technique for estimating pressure records using data from moored temperature sensors and nearby inverted echo sounders (IES). The IES travel time measurements, when combined with characteristics referred to as the gravest empirical mode (GEM), can predict full water column profiles of temperature. These GEM characteristics are developed using historical hydrography from the region, and the validity of the technique depends upon both having sufficient hydrography to characterize the local variability and on having the observed scatter about the GEM be small relative to the variations captured by the GEM (Meinen and Watts 2000). These requirements have been demonstrated for the western Newfoundland Basin region (Meinen and Watts 2000) and the Subantarctic Front region south of Australia (Watts et al. 2001). The IES-based temperature profiles are combined with the temperature measurements made by the moored sensors to estimate a pressure for each temperature measurement and, hence, for each collocated current measurement.

This technique works best for moored temperature sensors within the main thermocline. At those depths the vertical gradient of temperature is relatively large, and temperature provides a relatively accurate pressure estimate. At depths above and below the main thermocline the vertical gradient of temperature is small, and temperature provides a less accurate and thus less useful estimate of the pressure. For current meters outside the main thermocline there are two options for estimating the variations in pressure: first, a mooring design program can be used to determine the likely shape of the mooring line under the observed current regime and the differences between the pressure at various levels can be modeled; second, pressure measurements from other deployments of the same mooring design in similar conditions, whether during the same or previous experiments, can be used to determine the typical relationships between pressure deviations at different levels (e.g., Fig. 6).

Once pressure records at the various levels have been determined, then it is possible to proceed with mooring motion correction methods such as those presented in Hogg (1986, 1991). While the ''synthetic'' pressure records determined using the methodology presented in this paper are not as accurate as directly measured pressures, they will enable mooring motion correction of measurements made on a mooring on which the pressure sensors have failed. While it is clearly not cost effective to deploy an IES alongside every current meter mooring

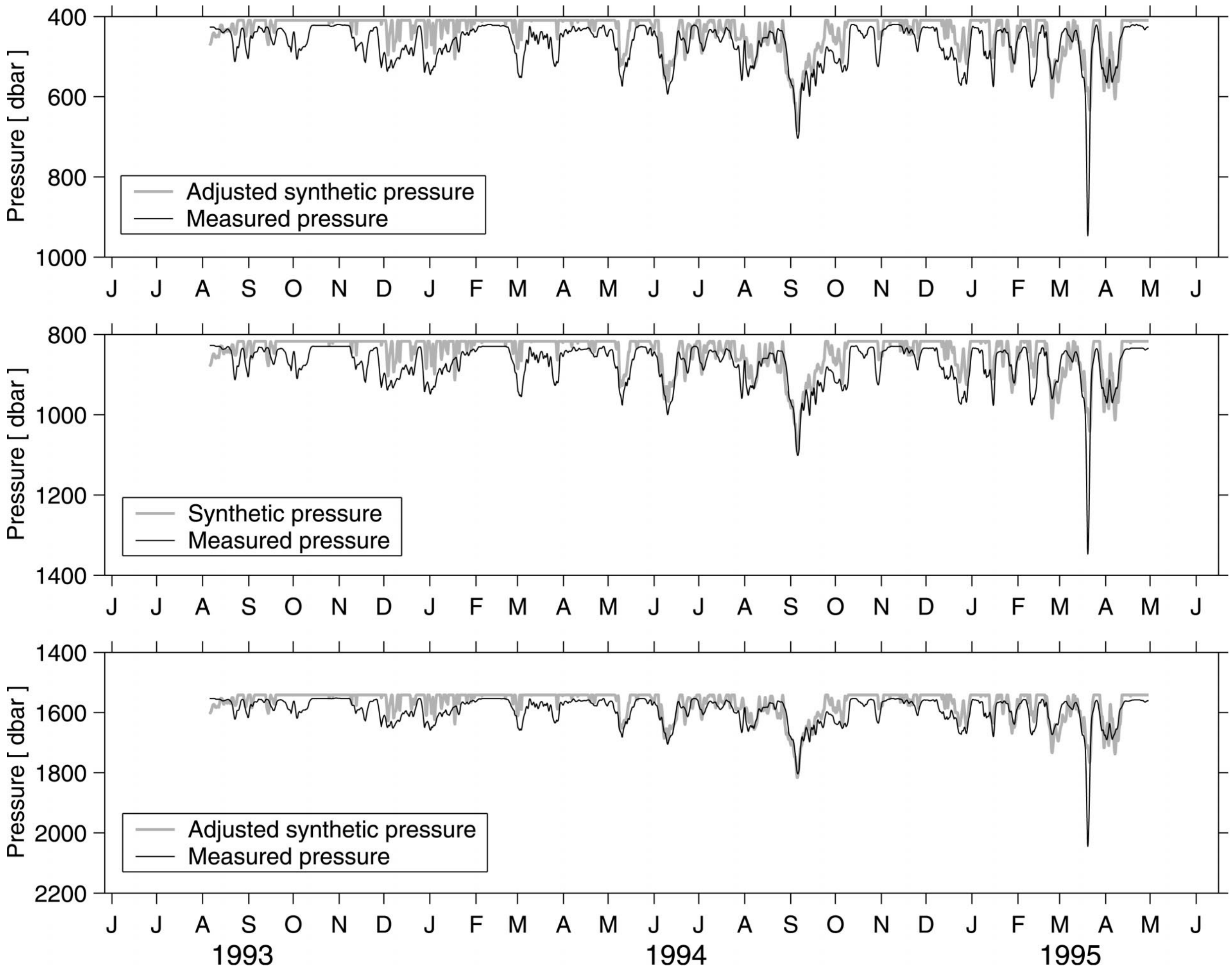

FIG. 7. Comparison between synthetic and measured pressures at NAC site 8 similar to Fig. 2; however, here the synthetic pressures at 420 and 1550 m have been replaced with adjusted synthetic pressures determined using the line lengths between instruments and the 1:1 relationship in variability with the 830-m instrument as illustrated in Fig. 6.

simply to provide information on mooring motion if the pressure sensors fail, it is becoming widely accepted that combined IES and current meter arrays are a powerful measurement technique. Over the past 10–20 years a number of large experiments have involved both types of instruments [e.g., SYNOP (Watts et al. 1995), the NAC study (Meinen and Watts 2000), SAFDE (Luther et al. 1997), and the recently completed the Office of Naval Research (ONR) funded Japan/East Sea Program], and such experiments are likely to be continued into the future. As such the technique presented here should be useful in these types of experiments.

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