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Continental slope sea level and flow variability induced by lateral movements of the Gulf Stream in the Middle Atlantic Bight

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Abstract

As described by [Csanady, G.T., Hamilton, P., 1988. Circulation of slope water. Continental Shelf Research 8, 565–624], the flow regime over the slope of the southern Middle Atlantic Bight (MAB) includes a current reversal in which southwestward flow over the upper and middle slope becomes entrained in the northeastward current adjacent to the Gulf Stream. In this paper we use satellite-derived data to quantify how lateral motions of the Gulf Stream impact this current system. In our analysis, the Gulf Stream's thermal front is delineated using a two-year time series of sea surface temperature derived from NOAA/AVHRR satellite data. Lateral motions of the Gulf Stream are represented in terms of temporal variations of the area, east of 73°W, between the Gulf Stream thermal front and the shelf edge. Variations of slope water flow within this area are represented by anomalies of geostrophic velocity as derived from the time series of the sea level anomaly determined from TOPEX/POSEIDON satellite altimeter data. A strong statistical relationship is found between Gulf Stream displacements and parabathic flow over the continental slope. It is such that the southwestward flow over the slope is accelerated when the Gulf Stream is relatively far from the shelf edge, and is decelerated (and perhaps even reversed) when the Gulf Stream is close to the shelf edge. This relationship between Gulf Stream displacements and parabathic flow is also observed in numerical simulations produced by the Miami Isopycnic Coordinate Model. In qualitative terms, it is consistent with the notion that when the Gulf Stream is closer to the 200-m isobath, it is capable of entraining a larger fraction of shelf water masses. Alternatively, when the Gulf Stream is far from the shelf-break, more water is advected into the MAB slope region from the northeast. Analysis of the diabathic flow indicates that much of the cross-slope transport by which the southwestward flow entering the study region is transferred to the northeastward flow exiting the region occurs in a narrow band roughly centered at 36.75°N, order 150 km north of Cape Hatteras. This transport, and thus the cyclonic circulation of the southern MAB, strengthens when the Gulf Stream is relatively close to the shelf edge, and weakens when the Gulf Stream is far from the shelf edge.

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1. Introduction

The oceanographic region near Cape Hatteras (CH), North Carolina (Fig. 1), is highly complex, encompassing a number of water masses and current systems. Extending offshore from CH is an eastward oriented shoal, called Diamond Shoals, that serves as a partial barrier to along-shelf flow (Pietrafesa et al., 2002; Bignami and Hopkins, 2003) and separates two oceanographically different regions: the Middle Atlantic Bight (MAB) and the South Atlantic Bight (SAB). Near Diamond Shoals, the Gulf Stream (GS), typically separates from the continental margin and flows into deeper water. In the region of this separation, lateral displacements of the GS tend to be small (Sun and Pietrafesa, 1996), with a standard deviation of order 10 km (Pickart and Watts, 1993). However, meanders grow quite rapidly downstream, and at 70°W the standard deviation of their lateral displacements is greater than 50 km (Halliwell and Mooers, 1983). The seasonal as well as interannual behavior of GS lateral movements has been quantitatively addressed with field measurements (Halkin and Rossby, 1985; Tracey and Watts, 1986; Watts et al., 1995) and with remotely sensed observations (Kelly and Gille, 1990; Lee and Cornillion, 1995, 1996a,b). In general, the GS is typically north (south) of its mean position in the fall (summer), a seasonal cycle that has been associated with large-scale wind and heating cycles (Worthington, 1976; Fu et al., 1987).

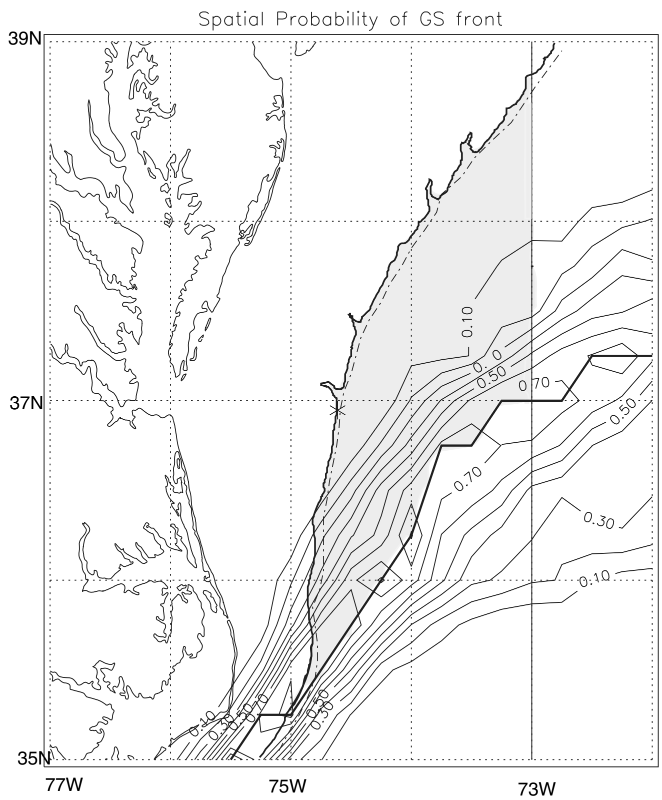

Fig. 1. Chart of the Gulf Stream (GS) scaled probability distribution front based on the digitized frontal edges shown in Fig. 2. The distribution was determined by counting the number of frontal points in each 0.25° × 0.25° square and dividing the resulting field by its maximum value. Note the downstream widening of the GS front distribution around its axis (thick solid line) of highest probability. The 200- and 750-m depth contours are drawn as solid and dashed lines, respectively. An asterisk marks the location of the SEEP current meter #9. The area discussed in the text is shaded.