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Variation in the Hatteras Front density and velocity structure Part 1: High resolution transects from three seasons in 2004–2005

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ABSTRACT

On the continental shelf near Cape Hatteras, cool fresh Mid-Atlantic Bight and warm salty South Atlantic Bight shelf waters converge alongshelf 90% of the time, causing strong alongshelf gradients in temperature, salinity, and density known as the 'Hatteras Front'. Mechanisms of shoreward transport in this region have long been a topic of interest, since many commercially important species spawn on the outer shelf, but utilize the adjacent Albemarle and Pamlico Sounds for nurseries, requiring some physical transport mechanism to move the eggs and larvae from the outer shelf to these nursery areas. One mechanism providing such shoreward transport is strong shoreward velocity along the cross-shelf oriented 'nose' of the Hatteras Front. The Frontal Interactions near Cape Hatteras (FINCH) project used shipboard ADCP and a towed undulating CTD to examine Hatteras Front property, density and velocity fields in August 2004, January 2005, and July 2005. Strong property gradients were encountered across the nose of the Hatteras Front in all cases, but the density gradient evolved in time, and along with it the dynamic height gradient driving the observed along-front cross-shelf velocities in the nose of the Front. In August and January FINCH data, MAB shelf waters on the north side of the Hatteras Front are less dense than SAB shelf waters, driving shoreward velocities along the Hatteras Front. By July, MAB shelf waters are slightly more dense than SAB shelf waters, with areas of weak seaward and shoreward velocities within the Hatteras Front. As Part 1 of a pair of contributions, this article focuses on FINCH data to illustrate the range of density gradients encountered and resulting cross-shelf velocities. Whether these observations are typical of variability in the Hatteras Front is explored in a second article, Part 2.

1. Background

On the continental shelf and slope near Cape Hatteras, Mid-Atlantic Bight (MAB) and South Atlantic Bight (SAB) shelf waters converge alongshelf 90% of the time in daily alongshelf transports (Savidge and Bane, 2001). Since shelf waters derived from north and south of Cape Hatteras have large differences in temperature (T) and salinity (S) characteristics, this convergence supports a strong alongshelf gradient in T and S expressed across the cross-shelf oriented "Hatteras Front" (Stefansson et al., 1971; Pietrafesa et al., 1994; Berger et al., 1995). Such convergence requires offshelf export of shelf waters through continuity, examined for the MAB shelf water component in several field studies, including the Shelf Edge Exchange Projects (SEEP and SEEP-II) and the Ocean Margins Project (OMP) (Walsh et al., 1988; Biscaye et al., 1994; Verity et al., 2002).

Mechanisms of shoreward transport in this region have also been a topic of interest (Checkley et al., 1988; Shanks, 1988; Stegmann and Yoder, 1996; Quinlan et al., 1999). Many commercially important species spawn on the outer shelf, but utilize the adjacent Albemarle and Pamlico Sounds for nurseries, requiring some physical transport mechanism to move the eggs and larvae from the outer shelf to these nursery areas. Persistent interest in gas and oil deposits on the shelf and slope raises the question of how any pollution resulting from such activities might reach and affect the ecologically and economically important sounds and beaches of North Carolina.

Velocities along the Hatteras Front provide one effective shoreward conduit in winter, first demonstrated by Savidge (2002) using mooring records (Fig. 1). In that study, the T and S gradients across the Hatteras Front did not completely compensate, such that cold, relatively fresh MAB shelf water was less dense than warmer, saltier SAB shelf water. The resulting dynamic height gradient across the Front was estimated to be of sufficient magnitude to drive observed shoreward alongfront velocities.

The Frontal Interactions near Cape Hatteras (FINCH) project was designed and carried out to investigate this shoreward transport mechanism. Using shipboard ADCP combined with a towed undulating CTD, the circulation and density fields

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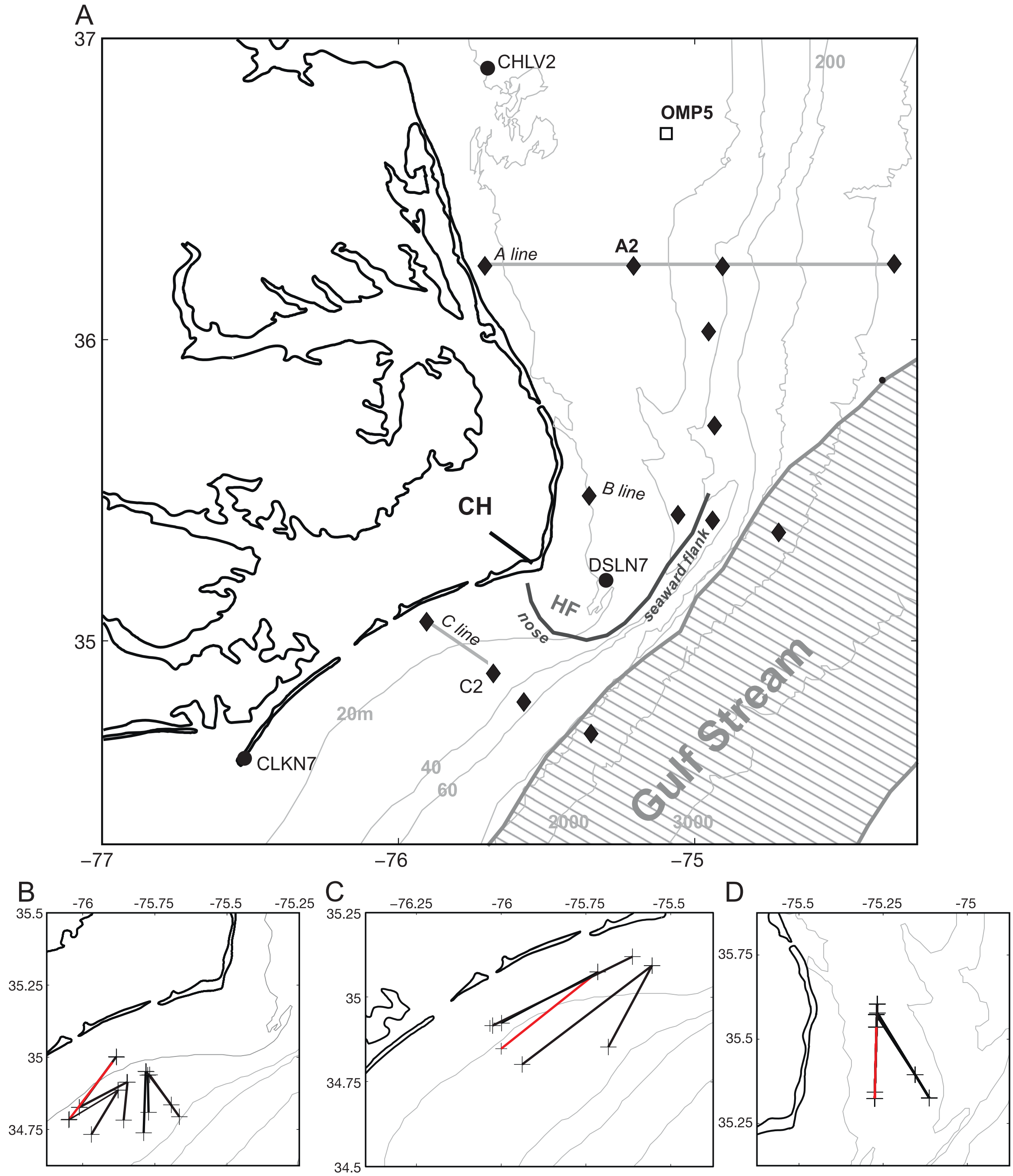

Fig. 1. Cape Hatteras region and measurement locations. Panel A: Cape Hatteras (CH) MMS field study site (March, 1992–February, 1994), with mooring locations (black diamonds) along three cross-shelf lines (lines A–C in panel A) and two additional shelf-edge moorings (between lines A and B). The hydrographic data shown in Figs. 6–8 were collected on cross-shelf transects along the lines defined by the A moorings and the C moorings. A schematic Hatteras Front (HF) shows both the cross-shelf oriented 'nose' of the Front and its more along-shelf oriented 'seaward flank'. The approximate mean position and width of the Gulf Stream is also shown. The lower panels show the FINCH transects in August 2004, January and July 2005 used within this paper. Red lines show locations of transects in Fig. 3. Together with the black lines, they indicate the locations of all transects included in the stream coordinate means shown in Fig. 5. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this article.)

associated with the cross-shelf nose of the Hatteras Front were intensively sampled in three field seasons: August 8–11, 2004, three 2–3 day forays in late January 2005, and July 19–21, 2005. The August data are described in detail in Savidge and Austin (2007), verifying strong property (T and S) and density gradients across the Front, and strong geostrophic shoreward velocities along its nose.

MAB shelf waters are known to undergo strong seasonal T variability, in both T ranges and strength of vertical stratification (Lentz, 2010; Castelao et al., 2008). SAB shelf water T also varies with season, with more modest stratification changes, as described in Blanton et al. (2003). Salinity evolution is much less seasonal than T in either SAB or MAB shelf waters, but both MAB and SAB T and S are subject to interannual variability (Blanton et al., 2003; Mountain, 2003; Castelao et al., 2008). Such seasonal or interannual variability may effect the density gradient across the Hatteras Front, and therefore the geostrophically driven shoreward velocities along its nose.

In this article, data collected in the January and July FINCH field seasons are compared to the August data to examine how