RADIUM ISOTOPES AS TRACERS OF COASTAL CIRCULATION PATHWAYS IN THE MID-ATLANTIC BIGHT

by

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Abstract

Pathways of exchange between the shelf and slope in the Mid-Atlantic Bight were investigated using a combination of radiochemical tracer and hydrographic measurements. The motivation was to provide evidence of transport routes for shelfwater that could be important to the balance of shelf-slope exchange, as well as to the biogeochemical fluxes across this crucial ocean boundary. The four radium isotopes, with half-lives of 4 days to 1600 years, a coastal source, and conservative properties in seawater, were used as coastal water mass tracers. The final study was comprised of data from 5 cruises, with a total of 8 cross-shelfbreak transects. Two areas were studied, a northern Mid-Atlantic Bight transect south of Nantucket Shoals, and a southern Mid-Atlantic Bight series of transects off the coast of Delaware. In addition, data were collected from the shelfbreak at Cape Hatteras crossing the western wall of the Gulf Stream to help determine sources of anomalous ^{224}Ra enrichment which was observed on several of the shelfbreak transects. Combined with the hydrographic data, radium measurements suggested a pathway for exchange in the Mid-Atlantic Bight that was not a direct advection of shelf water toward the slope. Rather, the evidence suggested limited direct exchange of surface shelf water across the shelfbreak front. This provides observational evidence that is consistent with models (e.g., Gawarkiewicz and Chapman, 1991) which predict the shelfbreak front will impede exchange. Furthermore, ^{224}Ra activity on the upper slope points to a rapid transport pathway for bottom water from the Cape Hatteras shelf via the Gulf Stream onto the Mid-Atlantic Bight slope. The radiochemical and hydrographic evidence suggests that recirculation around the slope sea gyre may be a more important pathway than direct cross-shelf transport.

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Chapter 1

Introduction

The focus of this dissertation project has been to help determine pathways of exchange between the shelf and slope in the Mid-Atlantic Bight using a combination of radiochemical tracer and hydrographic measurements. The motivation was to provide evidence of transport routes for shelfwater that could be important to the balance of shelf-slope exchange, as well as to the biogeochemical fluxes across this crucial ocean boundary. The four radium isotopes, with half-lives of 4 days to 1600 years, a coastal source, and conservative properties in seawater, were ideal candidates to conduct such a study.

Although research has been intensive in this area for the past 15-20 years, still only "crude estimates" of cross-shelf exchange rates exist (Loder et al. 1998). Physical observations and modeling of exchange across the shelfbreak over the past 15 years have clarified some of the processes operating there (Chapman and Lentz 1994; Gawarkiewicz and Chapman 1991; Pickart 2000; Houghton and Visbeck 1998), but exact mechanisms are still unclear. Loder et al. note that the estimates that do exist do not identify the mechanisms of exchange, where the exchange takes place, and how seasonal or longer variability affects the estimates. Gulf Stream ring effects on the slope and outer shelf have been noted along with other processes that are suspected to play some role (frontal eddies, flow through canyons, wind forcing) but the magnitude to which each contributes to cross-shelf exchange is considered to be "poorly known in general."

1.1 New uses for radium tracers

Previous work with radium tracers had observed smooth, exponential distributions across the South Atlantic Bight shelf that were used to estimate horizontal eddy diffusivity and groundwater inputs (Moore 1997; Moore 1996). I set out to expand this line of inquiry in several respects. First, short-lived radium tracers had not been used in the shelfbreak region. Preliminary measurements suggested that activities up to 200 km from shore were still high enough to make useful observations of shelfwater exchange across the shelfbreak front.

Secondly, physical circulation in the Mid-Atlantic Bight is characterized by processes which are highly energetic, episodic, small scale, and of short duration (Gawarkiewicz et al. submitted 2002; Gawarkiewicz et al. 1996b; Gawarkiewicz et al. 1990; Churchill and Cornillon 1991; Garvine et al. 1988; Garvine et al. 1989; Beardsley et al. 1985). These include many advective processes, such as Gulf Stream ring intrusion, entrainment of shelfwater streamers, wind forcing, bottom boundary layer transport, and effects of frontal eddies. Because of the nature of the circulation in the Mid-Atlantic Bight it appeared that short-lived radium could possibly be more useful as a tracer of small-scale events than of large-scale mixing. Previously, methods for determining mixing coefficients have assumed steady-state conditions with no advection, and thus were of limited use under realistic shelfbreak conditions. However, mechanisms of physical exchange such as shelfwater streamers or other small-scale advective mechanisms might be reasonably examined using radium isotopes.