A Flushing Model of Onslow Bay, North Carolina, Based on Intrusion Volumes

LARRY P. ATKINSON
Skidaway Institute of Oceanography, P.O. Box 13687, Savannah, GA 31406

LEONARD J. PIETRAFESA
Department of Marine Science and Engineering, North Carolina State University, Raleigh, NC 27607
20 September 1979

ABSTRACT

Onslow Bay, North Carolina, is repeatedly flushed by intrusions of Gulf Stream water. An exponential dilution model based on intrusion models indicates 20–60 days are required for 50% dilution of Bay waters.

1. Introduction

As noted recently by Blanton and Pietrafesa (1978) and previously by others, meanders of the Gulf Stream greatly influence the circulation of Onslow Bay, North Carolina. Meanders and eddies are a permanent feature of the Gulf Stream south of Cape Hatteras (Legeckis 1975, 1979) and others (Atkinson, 1977) have demonstrated that these

Fig. 1. Bottom temperatures in Onslow Bay between 14 July and 16 August 1976. The varying temperatures result from discrete intrusions of Gulf Stream water into the Bay. Surface temperatures varied from 27 to 29°C.
meanders are directly related to upwelling at the shelf break.

Recent hydrographic measurements show that the Bay was repeatedly invaded by upwelled Gulf Stream waters (Atkinson et al., 1980). Fig. 1 shows bottom temperatures in the Bay during four successive surveys during which time surface temperatures varied from 27–29°C, while bottom temperatures showed minima as low as 21.5°C. From these observations, Atkinson et al. were able to quantify the volume of summer subsurface intrusions. It was shown that water masses repeatedly invade the Bay during the summer months with a period of 14–40 days and each with a volume exceeding 20% (84 km³) of the Bay volume. Here we develop a flushing model for the Bay based on the concept of discretely intruding water masses and give examples using observed intrusion volumes and frequencies.

2. Exponential dilution flushing model

The activity of Gulf Stream intrusions in Onslow Bay implies that "flushing" of the Bay is an exponential dilution process which depends on intrusion volume and frequency rather than on diffusion caused by continual exchange. If true, the volume and frequency of the intrusions are critical to the flushing characteristics of the Bay. Intrusion volume measurements averaged 20% of the Bay volume and we use this as a typical value. Gulf Stream meanders occur about every 5–10 days (Webster, 1961) and presumably intrusions could occur on a similar period. However, one period of 40 days was observed by Atkinson et al. when no intrusions were noted. To demonstrate the exponential model we use periods of 5 and 20 days and intrusion volumes of 20%. The two lines generated by the model (Fig. 2) probably bracket true average characteristics. Fifty percent dilution is achieved in about 20 and 60 days depending on the frequency and volume. The center line is the dilution line from observations of two intrusions observed by Atkinson et al. using a probable lifetime of 31 and 14 days and volumes of 36 and 20% of the Bay, respectively.

We have considered the volumes of subsurface intrusions neglecting incursions of surface Gulf Stream waters. Inclusion of surface influxes would increase the calculated dilution rate. Our model also assumes complete mixing of the intruding water mass before removal, a process which does not always occur. If included this process would decrease the dilution rate.

3. Comparison to other flushing estimates

There are two other calculations of flushing time for Onslow Bay. One estimate (Stefansson et al., 1971) for the shelf area from mid-Onslow Bay to Cape Hatteras, using the freshwater volume/freshwater input technique of Ketchum and Keene (1955), yielded a flushing rate of 14 days for the area.

The second, using estuarine-like circulation patterns inferred from current meter data, determined the flushing rate of Onslow Bay to be 2.7–3 months (Blanton and Pietrafesa, 1978). This rate should be slower than that calculated by Stefansson et al. (1971) since Onslow Bay is less affected by the Gulf Stream than the area to the north.

Our estimates, which are not directly comparable since we calculated dilution rather than flushing rates, are comparable to those of Blanton and Pietrafesa (1978), confirming both the concept and results.

4. Conclusion

An exponential dilution model may be preferred in flushing or dilution studies of Onslow Bay since flushing of a pollutant from the Bay can be approximated by one of the dilution curves. By assuming the minimum and maximum volumes and frequencies of intrusions minimum and maximum dilution times can be estimated.

Acknowledgments. This research was sponsored by the Department of Energy under Contracts DE-AS09-77SR01025 and DE-AS09-76EY00902 to Atkinson and Pietrafesa, respectively. We appreciate Drs. D. Menzel and J. Blanton for comments and
discussion. We thank Ms. L. Land for typing and Mr. D. McIntosh for drafting.

REFERENCES


