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Caribbean current variability and the influence of the Amazon and Orinoco freshwater plumes

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Abstract

The variability of the Caribbean Current is studied in terms of the influence on its dynamics of the freshwater inflow from the Orinoco and Amazon rivers. Sea-surface salinity maps of the eastern Caribbean and SeaWiFS color images show that a freshwater plume from the Orinoco and Amazon Rivers extends seasonally northwestward across the Caribbean basin, from August to November, 3–4 months after the peak of the seasonal rains in northeastern South America. The plume is sustained by two main inflows from the North Brazil Current and its current rings. The southern inflow enters the Caribbean Sea south of Grenada Island and becomes the main branch of the Caribbean Current in the southern Caribbean. The northern inflow (14°N) passes northward around the Grenadine Islands and St. Vincent. As North Brazil Current rings stall and decay east of the Lesser Antilles, between 14°N and 18°N, they release freshwater into the northern part of the eastern Caribbean Sea merging with inflow from the North Equatorial Current. Velocity vectors derived from surface drifters in the eastern Caribbean indicate three westward flowing jets: (1) the southern and fastest at 11°N; (2) the center and second fastest at 14°N; (3) the northern and slowest at 17°N. The center jet (14°N) flows faster between the months of August and December and is located near the southern part of the freshwater plume. Using the MICOM North Atlantic simulation, it is shown that the Caribbean Current is seasonally intensified near 14°N, partly by the inflow of river plumes. Three to four times more anticyclonic eddies are formed during August–December, which agrees with a pronounced rise in the number of anticyclonic looper days in the drifter data then. A climatology-forced regional simulation embedding only the northern (14°N) Caribbean Current (without the influence of the vorticity of the NBC rings), using the ROMS model, shows that the low salinity plume coincides with a negative potential vorticity anomaly that intensifies the center jet located at the salinity front. The jet forms cyclones south of the plume, which are moved northwestward as the anticyclonic circulation intensifies in the eastern Caribbean Sea, north of 14°N. Friction on the shelves of the Greater Antilles also generates cyclones, which propagate westward and eastward from 67°W.

Keywords: Carribean; Amazon; Orinoco; Salinity; Drifter; MICOM; ROMS; CDOM; Anticyclone; Cyclone; Instability; Numerical modeling

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1. Introduction

River discharge plays an important role in the hydrological cycle and thermodynamic stability of the ocean. Knowledge of the variations in the extent and dispersal patterns of major river plumes and their mixing rates with oceanic water is critical in all aspects of continental shelf and regional oceanography. In particular, freshwater seasonally impinges on coral reef ecosystems, which affects the recruitment of larval reef fish (Kelly et al., 2000; Cowen and Castro, 1994) and fish mortality (Hu et al., 2004). The Caribbean Sea is influenced by the dispersal of the freshwater from the Amazon and Orinoco Rivers, which is discharged into the tropical Atlantic and advected into the Caribbean Sea (Fig. 1).

The Caribbean Current is a major current, which transports South Atlantic water through the Caribbean and into the Florida Current and the Gulf Stream. It is an important conduit of the upper part of the northward-flowing meridional overturning circulation (Schmitz and Richardson, 1991; Schmitz and McCartney, 1993). South Atlantic water crosses the equator in the North Brazil Current (NBC) and flows northwestward along the continental margin of South America in the form of a coastal current (Candela et al., 1992; Dessier and Donguy, 1994), in NBC rings (Johns et al., 1990; Fratantoni et al., 1995; Goñi and Johns, 2001), and as Ekman transport in the ocean interior (Mayer and Weisberg, 1993).

During the summer and fall each year a major part of the NBC retroflects near 6°N and feeds into the eastward-flowing North Equatorial Countercurrent which is intensified then. In spring, the Countercurrent weakens and reverses at the surface as a result of westward Ekman flow. Occasionally, pieces of the NBC retroflection pinch of as large NBC rings (around 400 km in overall diameter), which translate northwestward toward the Caribbean Sea (Johns et al., 2003; Garzoli et al., 2003; Goñi and Johns, 2003; Fratantoni and Glickson, 2002; Ffield, 2005; Frantantoni and Richardson, 2006). Recent results from the NBC Rings Experiment suggest that 8–9 rings form per year transporting roughly 9 Sv (Johns et al., 2003) with no marked seasonal variability of the formation rate but with

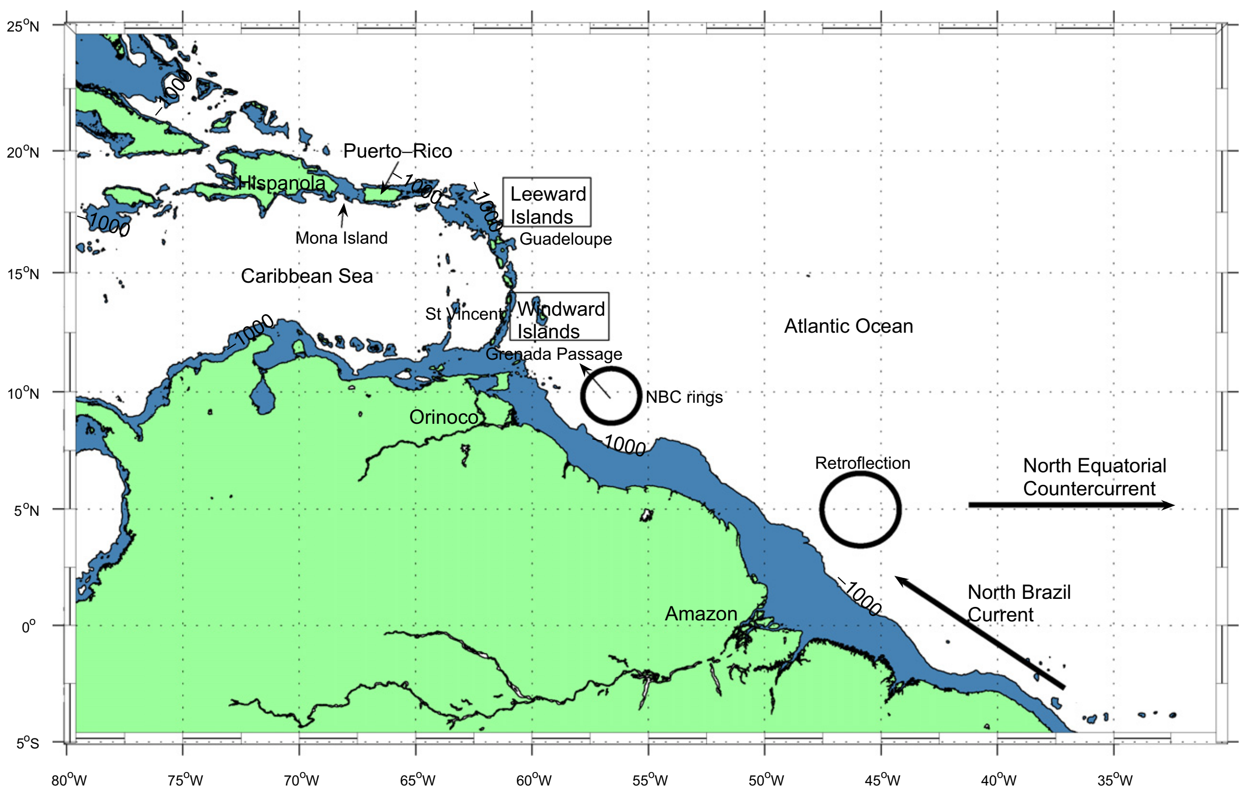

Fig. 1. Map of the Caribbean Sea and of the nearby tropical Atlantic showing the Amazon and Orinoco rivers along with the various groups of islands cited in the text.