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The Natal Pulse: An Extreme Transient on the Agulhas Current

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An analysis of satellite data collected over a period of 9 years as well as historic hydrographic data show that the northern Agulhas Current is subject to large, intermittent, and solitary meanders. These transient events, collectively named the Natal pulse, progress downstream at consistent rates of 21 cm/s. Upon reaching the area where the shelf broadens, their rate of progression slackens to 5 cm/s. They are present in some stages of development at least 17% of the time, extend offshore by about 170 km on average, and show a continuous lateral growth on moving downstream. With few exceptions the pulses are spawned as cold core, cyclonic, trapped lee eddies in the Natal Bight. They are held responsible for the intermittent coastal counter currents observed inshore of the Agulhas Current along the southern African coast and may play a crucial role in sediment distribution on the shelf.

INTRODUCTION

The Agulhas Current forms the southern part of the western boundary current system of the south Indian Ocean [*Paech*, 1926; *Michaelis*, 1923], reaching its full stature at about 26°S. It has as its sources water from the Mozambique Channel [*Saetre and Jorge da Silva*, 1984; *Harris*, 1972; *Lutjeharms*, 1976] and from the area east of Madagascar [*Lutjeharms et al.*, 1981], while a substantial degree of recirculation in a southwest Indian Ocean gyre has been shown to take place [*Harris and van Foreest*, 1978; *Lutjeharms*, 1976]. The current flows southwestward along the southern African coast until it overshoots the continent, retroflects at about 17°E [*Gründlingh and Lutjeharms*, 1979; *Harris and van Foreest*, 1978; J. R. E. Lutjeharms and R. C. van Ballegooyen, The Agulhas Current retroflection, submitted to *Journal of Physical Oceanography*, 1987], and flows eastward as the Agulhas Return Current along the Subtropical Convergence exhibiting high levels of dynamic mesoscale variability [*Lutjeharms and Baker*, 1980; *Lutjeharms and van Ballegooyen*, 1984] and eddy shedding (J. R. E. Lutjeharms and H. R. Valentine, Eddies at the Sub-Tropical Convergence south of Africa, submitted to *Journal of Physical Oceanography*, 1987).

As a major western boundary current, the Agulhas Current is unusual in showing very little meandering or divergence from its average position for a considerable part of its length. From about 27°S it follows the continental slope closely. Only from about 34°S, as the continental shelf widens downstream of Port Elizabeth (Figure 1) to form the Agulhas Bank, are shear-edge features and lateral meanders observed to disrupt the rectilinear flow significantly [*Harris et al.*, 1978; *Lutjeharms*, 1981*a*]. The dimensions of these lateral perturbations grow progressively causing eddy and ring shedding further downstream at the Agulhas retroflection [*Lutjeharms*, 1981*a*; *Gordon*, 1985; *Lutjeharms and Gordon*, 1987; J. R. E. Lutjeharms and R. C. van Ballegooyen, The Agulhas Current retroflection, submitted to *Journal of Physical Oceanography*, 1987].

Gründlingh [1983] analyzed the results of 307 hydrographic sections undertaken across the upstream section of the Agulhas Current between Cape St. Lucia (28°30'S) and Port Elizabeth (34°S) and established that along this stretch of narrow shelf the core of the Agulhas Current follows the continental slope with a lateral meandering displacement of less than 15 km, on average, to either side. However, of the 307 sections available, 14 were not even considered for the analysis as they exhibited altogether exceptional current core meanders in excess of 100 km, while in another 56 the current core was either extraordinarily weak or lay beyond the seaward range of the station lines. Station lines extended, on average 200 km offshore. Thus it may be inferred that during 23% of the crossings the Agulhas Current core lay well outside the narrow lateral range normally associated with it. *Pearce* [1977] also studied the current location using repeated sections off Durban, Richards Bay, and Port Edward. He found that it meanders between 25 and 100 km offshore. It may therefore be concluded that certain exceptionally large, nongeneric meanders disrupt the current path on occasion, while little lateral movement is the norm. The nature and causes of these meanders could not be ascertained with the data available at the time.

Studies using satellite imagery have successfully identified waves on the current border south of East London [*Harris et al.*, 1978]. These have phase velocities of about 20 cm/s. A similar phase velocity was determined for a meander upstream of Port Elizabeth, identified in 1973 by ship surveys [*Gründlingh*, 1979], but the wave amplitude of 200 km suggests that this particular meander might have had a different origin and dynamics. An extreme meander was observed once again in October 1983 [*Gründlingh*, 1986] and shown also to propagate downstream at about 20 cm/s. Remarkable features of this particular specimen were its location north of the Natal Bight at 29°S and the presence of an attendant mesoscale eddy seaward of the meander.

The separate identities of two types of perturbation features have been recognized as more suitable satellite images became available. It has been shown [*Lutjeharms*, 1981*a*] that downstream of Port Elizabeth the presence of a wider, steplike shelf facilitates the growth of small perturbations into substantial meanders with attendant shear-edge features and trailing plumes over the shelf. At irregular intervals, however, solitary excursions of the current with substantially larger amplitudes have been observed emanating from the direction upstream of Port Elizabeth. Named the Natal pulse for its assumed inception area in the Natal Bight, estimates of its average dimensions, based on 19 individual cases, gave a diameter of at least

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