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Observed impact of upwelling events on water properties and biological activity off the southwest coast of New Caledonia

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ABSTRACT

The upwelling events that follow strong trade wind episodes have been described in terms of their remarkable signature in the sea surface temperature southwest off New Caledonia. Upwelling brings deeper, and colder waters to the surface, causing 2–4 °C drops in temperature in a few hours, followed by a slower relaxation over several days. Upwelling may sporadically bring nutrients to the surface under certain conditions, and increase the biological productivity. Two multidisciplinary hydrographic cruises allow the impact of upwelling on the chemical and biological properties of the water to be documented. Both cruises took place in austral summer (December 2004 and December 2005), but the first cruise occurred during a strong upwelling event, while the second cruise occurred in calm conditions. The water properties and planktonic composition show important contrasts, with a strong southeastward current (the "ALIS current of New Caledonia") competing with the upwelling system. Our analysis suggests that, while observed productivities are far less than those of typical upwelling systems, some wind events in New Caledonia may contribute to biological activity. A currentmeter mooring, deployed during the second cruise, documents the ocean response to a changing wind field and the local impact of upwelling on currents and temperatures on the water column. The results are discussed, with the help of climatology, Argo float profiler data, satellite data and of a high-resolution numerical simulation.

1. Introduction

The western reef of New Caledonia is comparable to a steep wall that drops from the surface to 500 m almost immediately, and to 1000 m within 7 km from the reef. The reef is oriented southeast–northwest, almost at 45°, between latitudes 19 and 23 °S, and longitudinally between 163 and 167 °E. As a result, the topography is almost equivalent to a straight wall extending for 610 km, only interrupted by shallow passages that communicate with the lagoon.

The dominant winds are the southeasterly trade winds, which are prominent throughout the year with only slight seasonal variability (Caudmont and Maitrepierre, 2007). Because of their orientation parallel to the western reef, the trade winds are favorable to upwelling, and strong wind episodes are generally associated with sharp temperature drops off the west coast. While filaments of high biological productivity have been observed in satellite data off the west coast of New Caledonia (Dupouy, 1990), the region remains oligotrophic in comparison with upwelling systems observed elsewhere with production rates that are lower by a factor of five than those of coastal margins or high latitudes (e.g. Furnas and Mitchell, 1996; Ryan et al., 2002; Van Den Broeck et al., 2004).

Hénin and Cresswell (2005) were the first to document an upwelling effect off New Caledonia, with coastal temperature sensors showing drops of up to 5 °C associated with wind pulses. Their analysis of time series revealed that anomalies took about 5 days to develop, and satellite sea surface temperature (SST) images showed a corresponding band of cold water about 10 km wide appearing regularly against the reef, especially during austral summer (October–March). This was mostly confined to the southern half of the reef, but sometimes extending all the way to the north. Alory et al. (2006) expanded the investigation using coastal stations just outside the western New Caledonia reef, winds from

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satellite products and a climatology of vertical ocean temperature profiles. They were able to show that the upwelling process was modulated by the seasonally varying mixed layer depth. They noticed, from satellite chlorophyll (Chl-*a*) images, a local increase in biological activity during upwelling events. However, no local enhancement is noticeable in time-averaged Chl-*a* images, a possible consequence of the regular cloud cover near the coast that masks the region of interest.

These studies raised a number of question about the nature and the impact of the upwelling system of New Caledonia, along with the regional ocean circulation west of the island. While the surface cooling is well documented, the effect on the oceanic water column is not. An upwelling process, if it reaches deep enough, has the capability to bring nutrient rich waters to the surface, which would have an important impact on the local ecosystem, including the reef and the lagoon. Because the oceanic region is oligotrophic, this effect, even if it occurs irregularly, may be crucial in New Caledonia. To address these issues, two multidisciplinary cruises were carried out off the western reef, and a mooring line equipped with temperature and current sensors was deployed over a 4 month period (Section 2). The cruise and mooring results, documented in Sections 3 and 4 reveal interesting features, including a strong southeastward current flowing near the reef and that interferes with the upwelling system, and suggestion of nutrient enrichments related to upwelling. The results are considered with respect to regional data from an ocean climatology, Argo temperature and salinity profiles, a high-resolution numerical simulation and temperature and Chl-*a* satellite images (Section 5). The possible regional processes are discussed (Section 6), suggesting a regular occurrence of deep temperature cooling through upwelling but sporadic occurrence of nutrient uptake. The upwelling superimposes to an incoming eastward current and deviates it offshore.

2. Data

The two cruise trajectories and station positions are reported in Fig. 1. Both cruises were made during the austral Summer, when conditions for upwelling are optimal (Alory et al., 2006). They

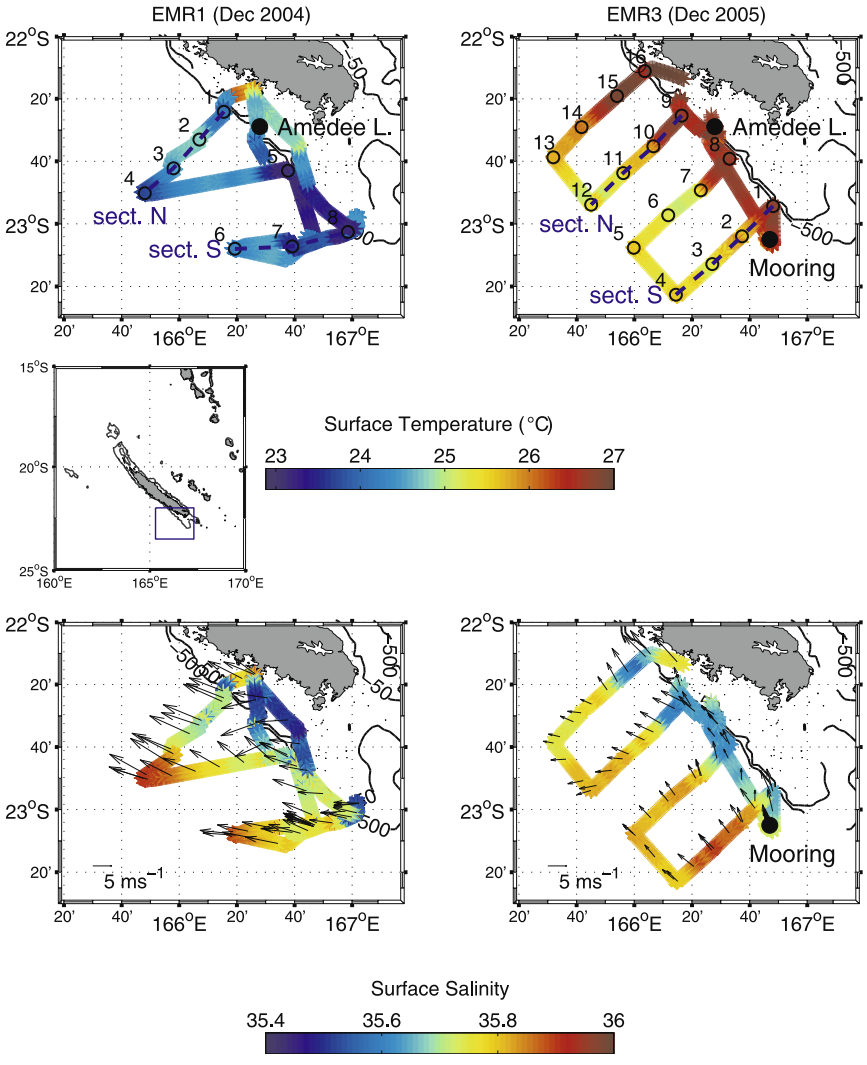

Fig. 1. EMERLIS cruise trajectories and station positions during (left) December 2004 (EMR1; upwelling situation); and (right) December 2005 (EMR3; rest situation). The circles and numbers (upper graphics) denote the station positions while the "North" and "South" sections that we define are indicated by the dashed blue lines. The color along the cruise track gives temperature (upper axes) and salinity (lower axes) as measured by the onboard thermosalinograph. The wind as recorded on the onboard meteorological station is reported on the lower axes (arrows). Topography is indicated by the 500-m and 50-m (delimiting the reef) isolines; Amédée Lighthouse (wind measurements) and the mooring position (2005) are indicated by the black circles.