Sea Surface Chlorophyll Concentration in the South Western Tropical Pacific, as seen from NIMBUS Coastal Zone Color Scanner from 1979 to 1984

(New Caledonia and Vanuatu).

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ABSTRACT

Examination of 40 processed cloud-free NIMBUS CZCS images over New Caledonia and Loyalty Islands provides a first view of the remotely sensed near-surface chlorophyll distribution. The major pattern of the phytoplankton abundance is the same as the one detected from the SURTROPAC survey: in winter, enrichment in the south of New Caledonia; in summer, extensive *Trichodesmium* blooms in the north east of New Caledonia. Much newer is the detection of mesoscale gyres trapped on the coast, narrow island mass effects, and generally detailed observations on the small and mesoscale variability around the islands.

1. Introduction.

The South Western Tropical Pacific ocean (SWTP) is considered as an oligotrophic region because of the generalization of the Deep Chlorophyll Maximum (Dandonneau, 1979). When the stratification is disturbed, nutrients usually blocked below the thermocline become available for the phytoplankton of the euphotic layer, leading to increases of the near-surface phytoplankton concentrations which can be remotely sensed from satellite platforms (ocean color) or detected from merchant ships surveys (SURTROPAC). Different possible causes of thermocline disturbances exist in the SWTP. The region (Fig.1) is rich in islands and the bathymetry is complicated by ridges (Norfolk and Fairway) and shoals above coral reefs, which enhance the vertical instability. The vertical mixing is high throughout the year, except from december to march, when a seasonal thermocline forms (Hénin et al., 1984).

Though, increases in Sea Surface Chlorophyll Concentrations (SSCC) towards the islands are not systematically observed by Dandonneau and Charpy, (1985). At the difference of Hawaiian Islands (Gilmartin and Revelante, 1974), no "island mass effect" was detected towards the island of Mare (Loyalties) (LeBorgne et al., 1985). Much strongly identified from the SURTROPAC survey, are the major SSCC increases north and south of the main island linked to the meteorological conditions (Dandonneau and Gohin, 1984).

Our goal is to describe the distribution and quantify the phytoplankton abundance in the region of New Caledonia with help of the ocean color remote sensing. As the NIMBUS-Coastal Zone Color Scanner measures the sea-irradiance in the blue light (Hovis et al., 1980), it allows the rapid and synoptic determination of the photosynthetic pigment distribution. If the cases of coastal upwellings and continental shelves are until now subjects of long-term interest in remote sensing, (Pelaez and McGowan, 1986,

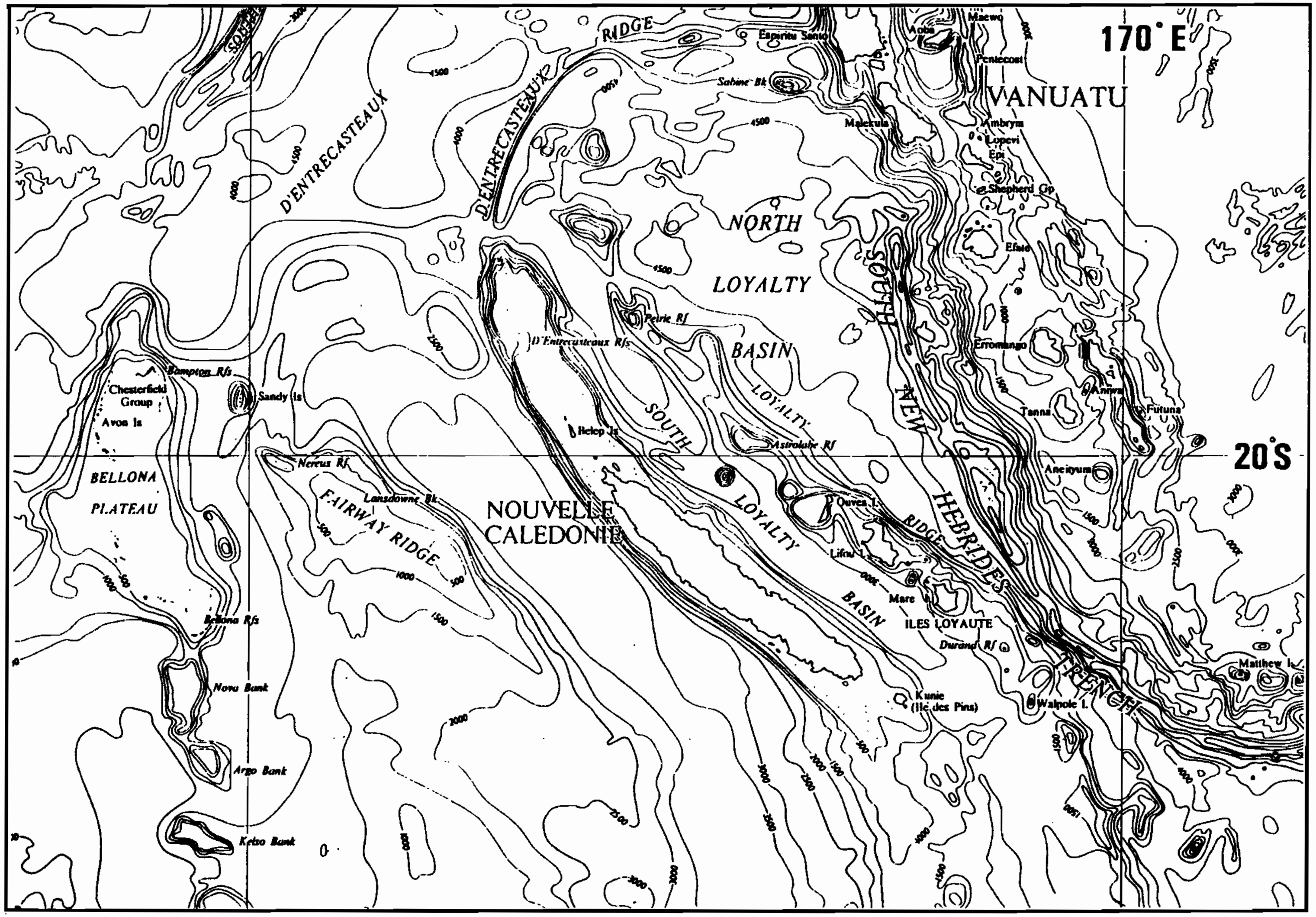

FIG.1. Detailed bathymetric map of the region around New Caledonia, Loyalty Islands and Vanuatu (from CCOP-SOPAC map, 1983 Fairway Ridge and Landsdowne Bank at 20°S, 164°E, Norfolk Ridge at 22°S, 165°E, Chesterfield Group at 19°S, 162°E.

Bricaud et al., 1987, Dupouy and Demarcq, 1987, Gordon et al., 1983, Viollier et al., 1988, Mueller-Karger et al., 1988), only a few studies were devoted to oligotrophic areas and islands rich regions.

2. Results.

The most cloud-free images from CZCS were selected over the area for the period 1979-1984. A fixed common geographic area was chosen and all the images were resampled on a Mercator projection onto this frame (160°E-170°E and 15°S-20°S ; 20°S-25°S). In this region, the chlorophyll is sensed over a depth of 20 meters (determined from the attenuation coefficient of the visible light, Gordon and McCluney, 1975). The deep chlorophyl maximum is never detected, which does not allow to estimate the total chlorophyll content of the water column from the ocean color sensor signal.

The results will be described (figures 2,3,4) by extracting the boundaries of the chlorophyll enrichments determined from the spatial gradients of the CZCS data.

a. Strong signal.

The strong signal of the data set is defined as high values of CZCS chlorophyll concentrations, detected more than once in the data set. Recurrent patterns have been observed at different dates, representative of the winter and summer conditions around New Caledonia.

* Winter conditions.

The 0.3 $mg.m^{-3}$ satellite chlorophyll isopleth (figure 2) shows the limit at 22°S between rich southern waters, and the poorer northern ones, in winters 1981 (April, May, June, July), 1983 (April and September) and 1984 (September 7 and 15). This frontal zone can be narrow in longitude (following the Norfolk ridge in May and September) or continuous over 5 or more degrees (July). The color fronts are indented by smaller eddies. As a strong thermal front was already detected during classical cruises (Jarrige et al., 1980), color and thermal fronts are probably coincident. In this case, the information is not new, as this latitude has been already described from the merchant ship survey (Dandonneau and Gohin, 1984) as the northward limit of the southern enrichment due to cooling and overturning by trades.

* Summer conditions.

The 0.2 $mg.m^{-3}$ CZCS chlorophyll isopleth delineates conspicuous features (figure 3), in December 1979, December 1980 and January 1982. Large patches of richer waters extend as far as 400 km between New Caledonia and the Vanuatu. They originate at the northern Loyalty Islands or New Caledonian northern lagoon. The pattern of January is remarkably well structured (large cyclonic vortex ending south in a arrow shape). Though no coincident measurements are available, the CZCS most probably detects three realizations of *Trichodesmium* blooms. As these algae are known to float at the surface and concentrate along convergence lines (positive buoyancy from gas vacuoles), observations of meanders on the CZCS images are not surprising. They are regularly made at sea or from aerial surveys when red tides of *Trichodesmium* are developed. An estimation of the nitrogen amount fixed by the bloom (these algae can fix the atmospheric nitrogen) has been made; according that the algae are *Trichodesmium sp.*, taking a mean fixation rate (Carpenter and Price, 1976), and assuming a duration of 10 days, the bloom of January 1982 could fix one ton of nitrogen (Dupouy et al., 1988). These irregular blooms of *Trichodesmium* were already identified as summer increase factors of SSCC, north of 22°S (Dandonneau and Gohin, 1984). The CZCS is the only tool to delineate the boundaries of such blooms, and then give an estimation of the nitrogen input in the upper layer.

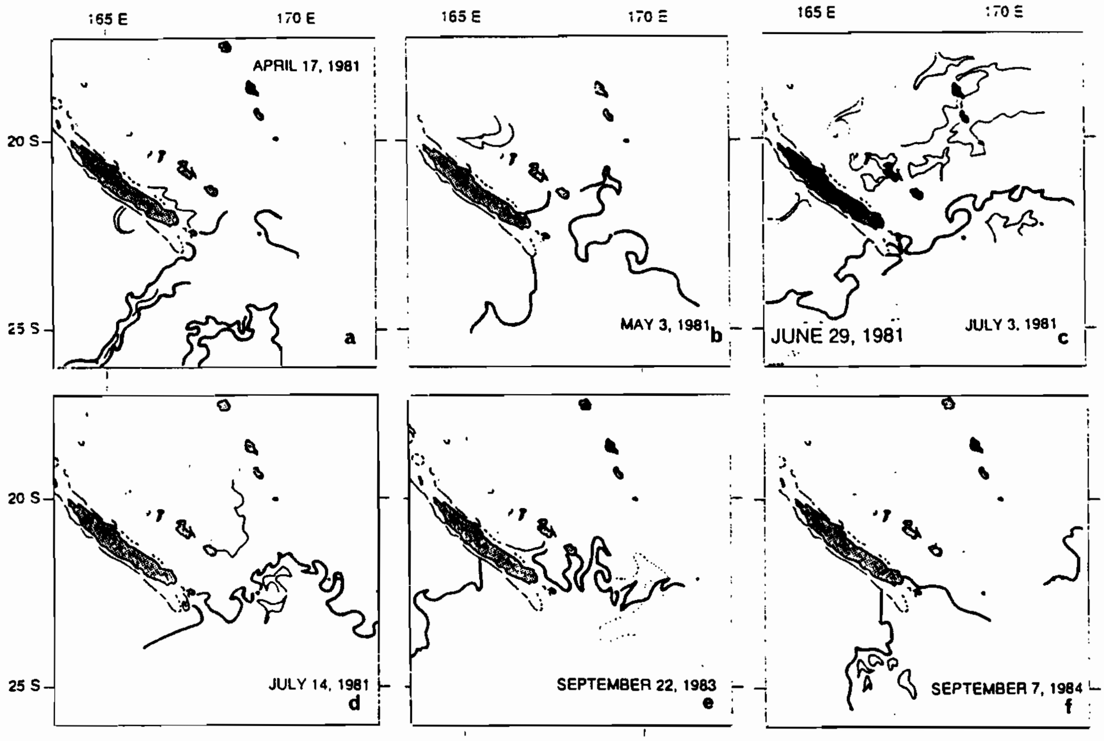

FIG.2. Schematic representation of the limit between pigment rich waters in the south, and poorer ones north of New Caledonia for 1981, 1983 and 1984 winter conditions. The CZCS pigment contour follows aproximately the 0.3 mg.m^{-3} isopleth and was smoothened for clarity (see III.1). a) April 17, 1981. b) May 31, 1981. c) June 29 and July 3, 1981. d) July 14, 1981. e) September 22, 1983. f) September 7, 1984.

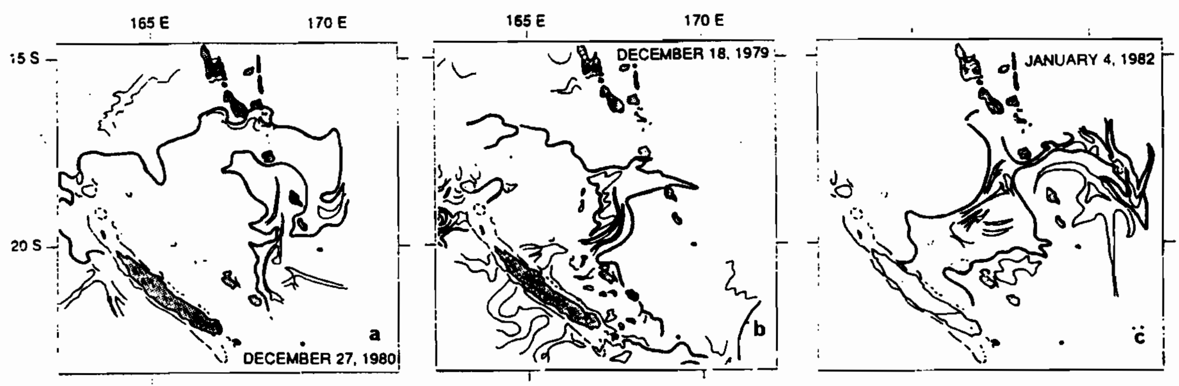

Fig.3. Schematic representation of the pigment rich waters for 1979, 1980 and 1982 summer conditions, showing the extension of Trichodesmium blooms. The CZCS pigment contour follows approximately the 0.2 mg.m^{-3} isopleth. a) December 27, 1980. b) December 18, 1979. c) January 4, 1982.

b. Secondary signal.

This secondary signal is defined as low chlorophyll patterns delineated by the 0.1 $mg.m^{-3}$ CZCS chlorophyll isopleth.

The swadth of the CZCS (1600 km) allows to show that the region surrounding the islands is, all over the year, richer than the more oligotrophic waters found north of 15°S or west of New Caledonia. This enrichment (low chlorophyll value), rather spatially continuous and constant over the year, was not previously evidenced.

The 0.1 $mg.m^{-3}$ CZCS chlorophyll isopleth delineates interesting features. The majority of these patterns are not observed with regularity in the data set. For example, plumes of rich chlorophyll waters originating in the lagoon, and extending along hundreds of kilometers offshore (northern and southern passages of the lagoon barrier). The northwestern coast of the main island is the site of eddies of great diameter (100km-200km) in November 1980 and April 1981 (see figure 4). The gyre of November is spatially coincident with an eddy of warm waters identified in the infrared (Petit and Gohin, 1982). Around the Loyalty Islands (Lifou and Mare), narrow plumelike meanders appear to be entrained from the coasts in winter 1983 (April and September) and winter 1981 (June to July), which agree with the G.E.K. current measurements (same dates). A bathymetric effect, defined as a chlorophyll rich patch surrounded by poorer waters, was detected many times above the Chesterfield lagoons, and twice above the Landsdowne Bank in the Fairway ridge (at 20°S, 164°E see map), in June 1981 and December 1979.

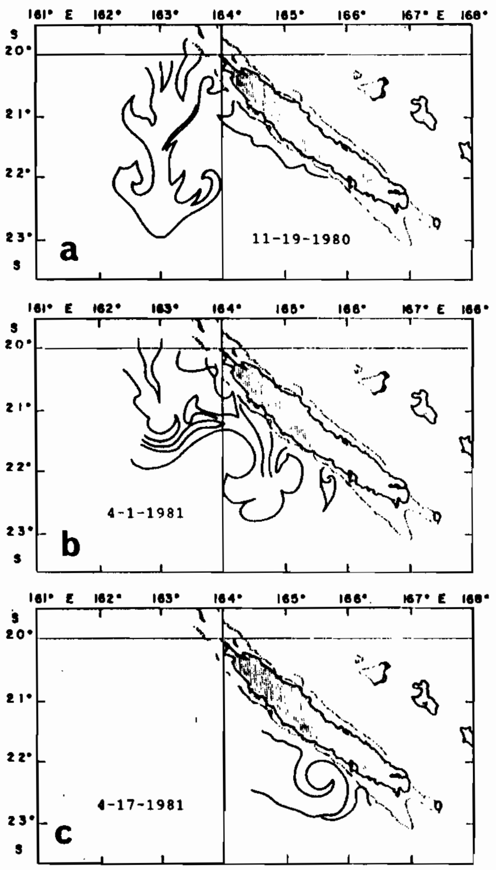

FIG.4. Schematic representation of the low chlorophyll patterns. The CZCS pigment contour follows the 0.1 $mg.m^{-3}$ isopleth. Best examples of trapped mesoscale eddies on the northwestern coast of New Caledonia. a) November 19, 1980. b) April 4, 1981 c) April 17, 1981.

3. Conclusions.

The strong signal defined as recurrent features (high chlorophyll enrichments) detected by CZCS, confirms the conclusions made from the observations of merchant ships during the SURTROPAC survey.

The secondary signal defined as low chlorophyll enrichments is interesting as it reveals new features, never detected from sea-measurements. These near-surface chlorophylls are related to the superficial circulation (eddies, 2-D turbulence, Ekman drift) which has been described as variable and low in this region (Hénin et al., 1984, Le Borgne et al., 1985). The island mass effects are shown by the CZCS, but they are difficult to isolate from the "archipelago" continuous enrichment. As this chlorophyll enrichment is rather continuous between lands, the total amount of pigment biomass, by taking into account the covered surfaces, should be compared to the other source of phytoplankton biomass in the Western Tropical Pacific (equatorial upwelling).

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