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Seasonal variability in satellite-measured surface chlorophyll in the Patagonian Shelf

Andrés L. Rivas[a], Ana Inés Dogliotti[b,*], Domingo A. Gagliardini[a,b]

[a]*Centro Nacional patagónico (CENPAT-CONICET), Boulevard Brown s/n, Puerto Madryn, Argentina*
[b]*Instituto de Astronomía y Física del Espacio (IAFE-CONICET), Pabellón IAFE-Ciudad Universitaria, C.C. 67-sucursal 28 (1428) Buenos Aires, Argentina*

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Abstract

Six years (January 1998—December 2003) of SeaWiFS ocean color satellite data are used to estimate monthly climatological means and to present the near-surface chlorophyll-a seasonal evolution in the Patagonian Shelf. The southern part of the shelf presents elevated chlorophyll concentrations from spring through autumn, while the northern part shows three regions with particular characteristics. The external region, bordering the 200 m isobath, presents elevated concentrations from spring through autumn supported by the nutrient-rich waters from the Malvinas (Falkland) Current. The central region presents a typical pattern of temperate regions, characterized by two well-defined maxima, a stronger spring bloom and a weaker fall bloom, and low chlorophyll values throughout summer (scarce availability of nutrients) and winter (light being the limiting factor). Even though the displacement direction of the spring and fall blooms do not agree with previous information reported in the literature, they are interpreted based on the heat exchange in the air–sea interface that controls the development and erosion of the seasonal thermocline. Finally, the coastal region presents less-marked seasonal variability and isolated small areas with elevated concentrations associated with frontal areas are observed. The spatial mean chlorophyll evolution, averaged over the whole shelf (less than 200 m depth), shows a marked annual cycle with high values from spring to autumn, supporting the importance of frontal regions as a fertilization mechanism. An increasing trend in chlorophyll concentrations, within the 6 years analyzed here (in the order of 23%), is apparent based on an increasing of the maximum annual values. From the comparison with in situ data it can be concluded that satellite information reproduces the spatial patterns of chlorophyll fields obtained from more classical data, while differences exist in absolute values obtained from both methodologies.

Keywords: Phytoplankton; Patagonian Shelf; Satellite ocean color; Seasonal variability

1. Introduction

Chlorophyll-*a* in situ data, collected by oceanographic cruises provide either non-synoptic, coarse resolution realizations of global processes or detailed, but time and site specific views of localized features and processes. On the other hand, satellite information provides quasi-synoptic, comprehensive coverage and excellent spatial/time resolution data. One of its limitations is the confidence of the estimated values based on global algorithms not validated or calibrated with in situ observations,

*Corresponding author. Tel.: +54 11 4789 0179; fax: +54 11 4786 8114.
E-mail address: adogliotti@iafe.uba.ar (A.I. Dogliotti).

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which is essential to ensure the optimal quality of the data. Another limitation is that satellite-derived chlorophyll-*a* concentrations estimates phytoplankton biomass content of the upper layer of the ocean only, the first attenuation depth, while its distribution throughout the entire euphotic zone is not taken into account. This is important in many ecological studies and in the estimation of primary productivity of the water column. And even a more important limitation is cloud cover that limits its spatial and temporal coverage, especially at high latitudes. The Patagonian Continental Shelf (Fig. 1) is a relatively poorly studied region far away from the main navigation routes. Consequently, the sparse availability of in situ data makes the use of satellite information especially attractive.

The Patagonian Continental Shelf (PCS) is identified in general terms as an area of high primary productivity. It appears in the satellite images as a region with high values of surface chlorophyll-*a* concentrations (Longhurst et al., 1995; Podestá, 1997; Reta and Carreto, 2000). Oceanic fronts present in the PCS control the distribution and intensity of the biological production observed in the area. In the entire Patagonian Shelf, the mixing induced by the tidal currents brings about high levels of dissipation and it can inhibit the development of seasonal thermocline, particularly in zones of topographic shoals. This creates thermal fronts in spring and summer that defines the border between stratified and vertically mixed waters (Glorioso, 1987; Martos and Piccolo, 1988; Glorioso and Flather, 1995; Piola and Rivas, 1997). Tidal fronts have been identified in the study area (see Fig. 1) in the San Matías Gulf's mouth, to the SE of the Valdés Peninsula, in the San Jorge Gulf's mouth, along most of the coast south of 47°S, and around the NW of Malvinas (Falkland) Islands (Carreto et al., 1981a, 1986; Glorioso, 1987; Lutz and Carreto, 1991; Glorioso and Flather, 1995; Rivas and Dell'Arciprete, 2000; Bava et al., 2002; Sabatini and Martos, 2002; Acha et al., 2004; Bogazzi et al., 2005). Another type of oceanic front in the region is clearly distinguished south of 38°S coincident with the external shelf border (approximately 200 m isobath) and it is denominated shelf-break front (Fig. 1) (Brown and Podestá, 1997; Podestá, 1997; Bava et al., 2002; Bogazzi et al., 2005). The shelf-break front is a quasi-permanent thermohaline boundary between shelf subantartic waters and colder, saltier and nutrient-rich waters of the Malvinas (Falkland) Current flowing northward along the shelf-break.

The annual evolution of chlorophyll's content, on the Patagonian Shelf, has been documented using in situ data from different oceanographic cruises (Brandhorst and Castello, 1971; Carreto et al., 1981b). In particular, the North-Patagonian gulfs have been thoroughly surveyed (Carreto and Verona, 1974; Carreto et al., 1974; Verona and Carreto., 1974; Charpy and Charpy-Roubaud, 1980a, b; Charpy et al., 1982, 1983; Sastre et al., 1997; Gayoso, 2001). In addition, Podestá (1997) shows a first approach of seasonal chlorophyll-*a* content in the shelf using Coastal Zone Color Scanner (CZCS) satellite data.

In an early work Brandhorst and Castello (1971) present two charts of the spatial distribution of surface chlorophyll-*a* concentration in the Argentine Sea, one for austral summer (February and March) and one for austral winter (June and July). They were made with data obtained during surveys Pesquería III and IV (Proyecto de Desarrollo Pesquero, 1968a, b) and complemented with information published in the Texas A. & M. University (1963, 1964a, b). In spite of the limited number of stations used and the coarse spatial resolution, the authors identify in summer a chlorophyll-*a* maximum with values up to 5 mg m^{-3} next to the shelf-break area, west of the Malvinas (Falkland) Current axis; some isolated small areas with values around 1 mg m^{-3}, and over the continental shelf, south of 48°S, values higher than 1 mg m^{-3}. Furthermore, they point out the strong relation existing between chlorophyll-*a* and nutrient distributions. During winter period, they show the presence of a highly productive tongue extending over the central shelf from the mouth of the Río de la Plata to 43°S, with values higher than 2 mg m^{-3}, and a considerable decreasing of the observable values next to the slope and also in the southern part of the shelf (at latitudes higher than 45°S). This decline was attributed to the attenuation of the solar radiation and the homogeneous vertical distribution of phytoplankton due to the absence of a thermocline.

Carreto et al. (1981b) analyze the distribution of nutrients, phytoplanktonic pigments, cell number and phytoplanctonic composition in early austral winter (June 17–July 18, 1978) in the northern area of the shelf (between 43 and 36°S), and in early austral spring (September 21–October 12, 1978) in the coastal zone, where bottom depth is less than 100 m (between 47 and 37°S). In the winter cruise,