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Quantitative estimation of the influence of surface thermal fronts over chlorophyll concentration at the Patagonian shelf

Andrés L. Rivas *

Centro Nacional Patagónico (CENPAT-CONICET), Boulevard Brown s/n, 9120 Puerto Madryn, Chubut, Argentina and Universidad Nacional de la Patagonia San Juan Bosco, Sede Puerto Madryn, Argentina

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Abstract

Eighteen-year (1985–2002) mean monthly SST Pathfinder data with 9 km spatial resolution have been used to estimate surface gradients by finite differences. Then the seasonal climatological means have been calculated from the intensity of these gradients, and surface thermal fronts present in the Patagonian Continental Shelf (PCS) have been located. Moreover, 6 years (1998–2003) of SeaWiFS data with approximately 4 km spatial resolution have been used to estimate monthly composite images of surface chlorophyll concentration, after which seasonal climatological means distributions have been generated. Both seasonal distributions have been analyzed together and by combining the knowledge of oceanographic processes and phytoplankton responses to light and nutrient availability, regions where the presence of a thermal front affects photosynthetic activity have been identified. Subjective criteria have been applied to define eighteen areas where phytoplankton biomass is influenced by the presence of a thermal front. In these areas, the surface chlorophyll (spatial mean and total), its relationship with the surface chlorophyll of the whole region, and the seasonal evolution of this relationship have been calculated. All frontal areas cover less than 15% of the total surface, but they contribute with over 23% of the phytoplankton annual mean biomass. Considered as a group, during summer they show high chlorophyll values very similar to those in spring. During the cold period, when the water column is vertically mixed in practically the whole of PCS, the influence of physical fronts over the biological production is minimum. The frontal zone image remains clearly defined during summer, when approximately 85% of the area will have a determined mean chlorophyll concentration, while the other 15% has a 2.45 times larger value. While three pattern trends have been identified in the frontal areas, only two of them condition the pattern of the group, due to their horizontal extension.

Keywords: Fronts; Patagonian Shelf; Satellite; Physical–biological influences

1. Introduction

Richardson et al. (1985) claimed that there is a natural tendency to publish those cases in which a front is associated with high values of chlorophyll, and that the cases where high values of chlorophyll are not found near a frontal zone, are less diffused. Perhaps for this reason ocean frontal zones are in general associated with major biological activity and high productivity levels. Quantitative verification of this assertion is not simple. It requires, for example, an adequate definition of the term "frontal zone", a demarcation of the area where the presence of a front affects biological activity and the definition of the variables that allow to follow the process.

An oceanic front is a region where a sudden change of any property occurs and where the horizontal gradient

* Tel.: +54 2965 454024.
E-mail address: andres@cenpat.edu.ar.

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of this property achieves higher values. Fronts are not necessarily exclusive of the surface, nevertheless, if the aim is to localize all fronts present in a specific moment in a vast region, the need for synoptic data places satellite observations in a privileged position, although these only allow the identification of surface fronts.

The temperature in the Patagonian Continental Shelf (PCS) is regulated mainly by the surface heat flux, which has a very marked annual cycle, shifting horizontal advection to a secondary level (Rivas, 1994; Rivas and Piola, 2002). This is why in almost all the region the temperature shows a clear annual signal (Podestá et al., 1991; Rivas, 1994) and regulates the development and erosion of the seasonal thermocline that conditions the stability of the water column. Surface temperature fronts identified with satellite imaging (SST) are, in general, more numerous and more intense during the warm austral season (October–March), when the surface heat flux is from the atmosphere to the ocean (Fig. 1). They are located at the boundary between a strongly stratified zone with high surface temperature, and a colder and more homogenous vertical one. While atmospheric heat flux is used exclusively for heating a shallow surface layer when the water column is strongly stratified, the same amount of energy makes the temperature rise in a deeper water layer in a weakly stratified column. This is reflected in the horizontal surface temperature gradient. There are chiefly three mechanisms that allow the proximity of water masses with different stability degree: i. all along the continental shelf-break, shallow subantarctic shelf waters meet the cooler, more saline and vertically highly mixed waters of the Malvinas current, ii. in coastal zones the vertical shear induced by strong tidal currents at particular topographic shoals, generates areas that are vertically well mixed even during the warm season, and iii. in zones near a significant continental inflow of fresh water, salinity may be important in the regulation of vertical stratification. In this case, as stratification of the water column is caused by salinity differences, it might continue in the surface cooling period, allowing the identification of surface temperature gradients in the cold season.

The former simplified explanation of thermal fronts found in the PCS allows us to infer the importance of these systems in biological activity. If these surface fronts are

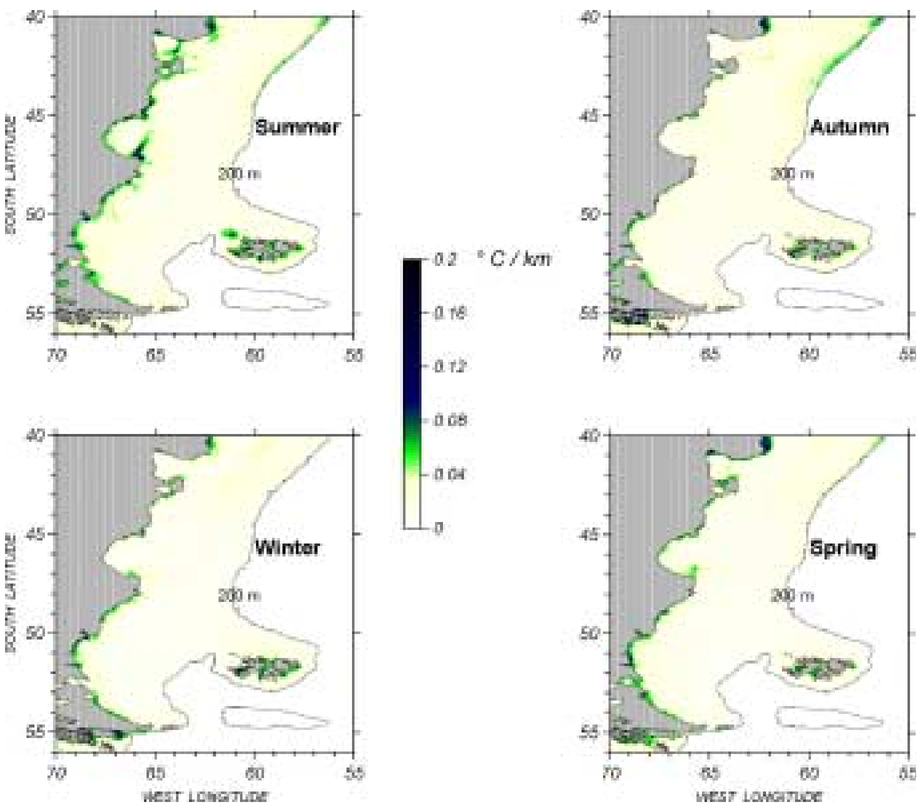

Fig. 1. Mean seasonal SST gradient magnitude (in °C km^{-1}) in the PCS (depth < 200 m) for summer (January–February–March), autumn (April–May–June), winter (July–August–September), and spring (October–November–December), for the 1985–2002 period. Frontal pixels are those with gradient magnitude > 0.045 °C km^{-1}.