IMPLEMENTATION OF NEW TECHNOLOGIES TO MONITOR PHYTOPLANKTON BLOOMS IN THE SOUTH OF CHILE

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ABSTRACT

A pilot project has been carried out to demonstrate the applicability of remote sensing in the Xth region of Chile, related to the monitoring of algal blooms. Most of the fish farms of the country are located in this area, where considerable economic losses for this activity are the consequence of algal blooms. The implementation of new technologies to monitor this natural disaster is one of the main goals of local institutions. The project has been developed using ENVISAT/MERIS and AATSR images and oceanographic instrumentation in order to improve the information of the ongoing coastal monitoring programs.

1. INTRODUCTION

Chile has coastal regions along its 2.00609 Km². Due to the very long coastline and extremely spotted area in the south of the country the only way to monitor oceanographic events is from space.

Since 1972 Harmful Algal Blooms (HAB) has become a growing problem in Chile, as one of the main economical activities in the south of the country is the exploitation of natural marine and aquaculture resources. The implementation of new technologies to improve the prediction of HAB is one of the main objectives of national and international projects related with this field of research. Remote sensing of ocean colour has been proposed in a consolidated report of the International Ocean Colour Coordinating Group (IOCCG, 2000) to broach the monitoring of algal blooms.

Nowadays the Chilean fish farming industry is the world leader in the production of the species mentioned in table 1. Algal blooms have a severe impact on the biomass in the cages by mechanically damaging in their gills. Additionally the fishes are suffocated due to the depletion of dissolved oxygen in the water. At last the feeding behaviour is modified due to the very poor visibility.

Table 1. Chilean fish farming biomass stock per year and exportation data.

<table>
<thead>
<tr>
<th>Main Species</th>
<th>Total Sites</th>
<th>Operating Sites</th>
<th>Biomass stock per year (Tons)</th>
<th>USD Exported at the end of 2003.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlantic Salmon (<em>Salmo salar</em>)</td>
<td>360</td>
<td>40</td>
<td>400,000 to 450,000</td>
<td>1,200 × 10⁶ USD</td>
</tr>
<tr>
<td>Coho Salmon (<em>Oncorhynchus kisutch</em>)</td>
<td>40</td>
<td></td>
<td></td>
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<tr>
<td>King Salmon (<em>Oncorhynhus tsavwytscha</em>)</td>
<td></td>
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<td></td>
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<tr>
<td>Rainbow trout (<em>Oncorhynchus mykiss</em>)</td>
<td></td>
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</tbody>
</table>

Actual losses due to phytoplankton blooms --------- more than 12 millions USD (Aquatoxsal, 1997).
Potential losses due to phytoplankton blooms -------- more than 50 millions USD (excluding human health and shellfish industry losses)

Since 1986, a local institution carries out a standardized monitoring program, in relation with algal blooms, for the fish farming industry. This institution is the responsible for the coordination of the scientific information for the adequate management of resources and for sustainable development. Cooperation with several companies, as Mariscope Chilena, has been established to enhance the technological development and to improve the current monitoring programs. Mariscope carries out this project through its experience on remote sensing data management, physical and biological oceanography know-how, and oceanographic instrumentation in the company at disposal.

The objective of this project is to demonstrate the applicability of remote sensing to forecast phytoplankton bloom events using MERIS and AATSR images. The prediction of algal blooms will lead to diminish the biomass losses in the industry and therefore to improve the efficiency of the fish farming activities.
During the austral summer 2002, a considerable bloom of the dinoflagelate *Alexandrium catenella* occurred in the area (Clement et al., 2002). Some SeaWiFS images demonstrated the potential of the technique in the region (Rodriguez and Arancibia, 2002).

![Aerial photograph of a phytoplankton bloom affecting some cages in the South of Chile.](image)

During this project the vertical distribution of phytoplankton biomass in the water column has been analyzed, to determine the main algal groups. The final results of the validation of the ENVISAT data analyzed in the region will be available in the near future.

2. METHODOLOGY

The concentration of up to five algal classes has been measured using a Fluoroprobe in the water column. This instrument measures with high sensitivity (equivalent to 1 ppm) phytoplankton concentrations by fluorescence (Fig. 2). The specific patterns of algae fluorescence- the fingerprints- are used to quantify algal divisions. The light sources are LEDs with selected wavelengths. The instrument is also equipped with temperature and yellow substances sensors.

Water samples are taken at 5 standard depths in 5 areas of the region (Fig. 3) to carry out the taxonomical identification. Additionally transects have been carried out in the area, as the one in fig. 3, from last 28th October.

33 MERIS images and 40 AATSR images from ENVISAT were received in the frame of an ESA/Category 1 project. MERIS L1 data was used between March and July 2003. Afterwards L2 data was available from the corresponding ESA PACs.

![Fluorescence spectra of light-emitting diodes](image)

![Diagram of Fluoroprobe](image)
3. RESULTS

An algal bloom was detected during April 2003, using MERIS data. The Maximum Chlorophyll Index, MCI (Gower & King, this volume) was applied (Fig. 3) to level 1 products. The AATSR images (Fig. 4) demonstrated the presence of fronts in the affected area. This physical oceanographic condition benefits the maintenance of the bloom. Water samples confirmed the presence of a *Gymnodinium* species, responsible of the green water discolouration in the area. It caused a very important decay of dissolved oxygen in the water, which in turn caused fish starving in salmon cages.

![Fig. 4: ENVISAT/MERIS MCI, 31 March 2003 (a), and SST (ºK) from the instrument AATSR (b).](image)

At the beginning of July 2003, higher concentrations than in the period before were detected in some areas around the big Island of Chiloé (Fig. 5). Fig. 5, shows the presence of oceanic fronts; features which can favour the development of phytoplankton, especially the division of dinoflagellates, as the Fluoroprobe measurements. Due to its capability of motion this organisms move around the front areas. Therefore they have some advantages to use the nutrients concentrated in those fronts (Mann & Laziers, 1996). From historical (Clement et al, 2001) and local knowledge (Alvial, pers. comm) two different reasons have been proposed for the developments of blooms: the first is the open ocean origin and the second are local conditions which favour the growing of the algae.

![Fig. 5: Chlorophyll concentration (µg·l⁻¹) from MERIS RR L2 product (a), and SST (ºK) from AATSR_NR (b) in the southern area of the region of study for 1st of July.](image)
Due to strong regional differences, areas can be defined with specific oceanographic patterns. For example, in the northern area of the region studied some cold water masses coming out the Reloncavi Estuary has been observed. This cold water masses move across the Gulf of Ancud and reaches the western area of this Gulf, increasing its nutrient supply. A great number of fish farms are located here, where dinoflagellates blooms are very frequent.

Fig. 6: Strong front in the Gulf of Ancud. Area highly influenced by the nutrient rich freshwater input from the Reloncavi Estuary. Temperature result (°K) from product AATSR of 11th of July 2003.

Fig. 7: Temperature (a) and total pigment concentration (b) along the section carried out last 28th of September in the Gulf of Ancud.
At the beginning of spring, high concentrations of phytoplankton up to 12 (µg·l⁻¹) were observed during the in situ measurements. Fig. 8, represents the time series on the monitored northwester area. These results correspond to the remotely sensed concentrations measured, as demonstrates fig. 9 of 14th of October. After this period the cloud coverage has been very high and therefore the phytoplankton population could not develop the typical concentrations of the austral spring bloom.

Good results of validation have been obtained from the comparison between the in situ temperature and chlorophyll measurements and the observations from the space. The strong correlation results are higher than 96% for the SST data and more than 86% for the total phytoplankton chlorophyll.

4. CONCLUSIONS

This has been the first time ocean colour observation from remote sensors in this area found their application. Moreover, it has been the first application of ENVISAT in Chile, implicating the aquaculture industry.

During the development of this project the applicability of the technique to monitor phytoplankton bloom has been shown. The prediction of the development of new blooms will be possible in the following critical periods. The use of ancillary data from water measurements and in situ samples will give information about the specifically composition of the blooms.

These results lead to the financial support of a pre-operative project where the following milestones will be archived:
• improvement of the coastal monitoring,
• reduction of economic losses,
• enhancement of efficiency,
• create an “algal forecast”,
• prepare the operative programme which be the next step.

5. ACKNOWLEDGMENTS

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6. REFERENCES


Gower, J., Stephanie King, Wei Yan Gary Borstad and Leslie Brown (this volume), Use of the 709 nm band of MERIS to detect intense plankton blooms and other conditions in coastal waters.

