Application of remote sensing in the Benguela ecosystem

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Project description

The overall objectives of this project were to a) investigate algorithms for generating ocean colour products applicable to the Benguela, and b) to use the outputs in association with satellite-derived SST imagery to study upwelling processes and plankton dynamics in different parts of the system at various spatial and temporal scales. The project is important for improving the quality of satellite-derived ocean colour products, and for improving understanding of the way in which the ecosystem responds to upwelling events, increasing the value of satellite imagery in environmental early warning systems.

The major portion of the research was undertaken by a contracted investigator (Scarla Weeks) whose tasks included: (1) optimising the processing of high resolution SeaWiFS data for the Benguela system, (2) observing hydrogen sulphide eruptions off Namibia through satellite imagery, (3) monitoring the evolution of a coccolithophorid bloom in the southern Benguela, and (4) developing chlorophyll and temperature indices for the system, with a focus on the southern Benguela. In addition, Chris Bartholomae investigated temperature and ocean colour variability off Namibia using high resolution satellite data in support of resource management, and in related studies supported by the IRD/IDYLE Programme, Claude Roy used low resolution (4 km) temperature data to investigate the implications of upwelling variability for anchovy recruitment in the southern Benguela. Also as an IRD/IDYLE project, Herve Demarcq developed an integrated chlorophyll index from low resolution SeaWiFS data to examine the temporal and spatial variability of phytoplankton production in the Benguela, and developed temperature and chlorophyll climatologies for the ecosystem.

Achievements

The main achievement of this project has been the generation of a large amount of high-quality satellite imagery, from which much has been learned about near-surface physical and biological processes in the Benguela system. Some particular examples are highlighted here.

Optimisation of processing parameters

Following a detailed investigation into the SeaWiFS bio-optical algorithms, some of the processing parameters were modified to optimise them for use in Benguela regional waters. It was found that constituents other than chlorophyll were at times contributing significantly to the in-water light field, and that because of major events such as hydrogen sulphide eruptions in the northern Benguela, no one set of processing parameters was adequate for processing all of the data over a long time series. A quantitative analysis of high resolution NOAA AVHRR and SeaWiFS ocean colour data for the southern Benguela ecosystem was undertaken, and initial operational indices derived for its use in ecosystem studies.

Hydrogen sulphide eruptions

High resolution ocean colour satellite images of sulphide-laden surface water (lower panel, Fig. 1) have shown that hydrogen sulphide eruptions off central Namibia are much more frequent and extensive than previously believed, and consequently probably have far more serious consequences for the ecosystem than was previously thought.

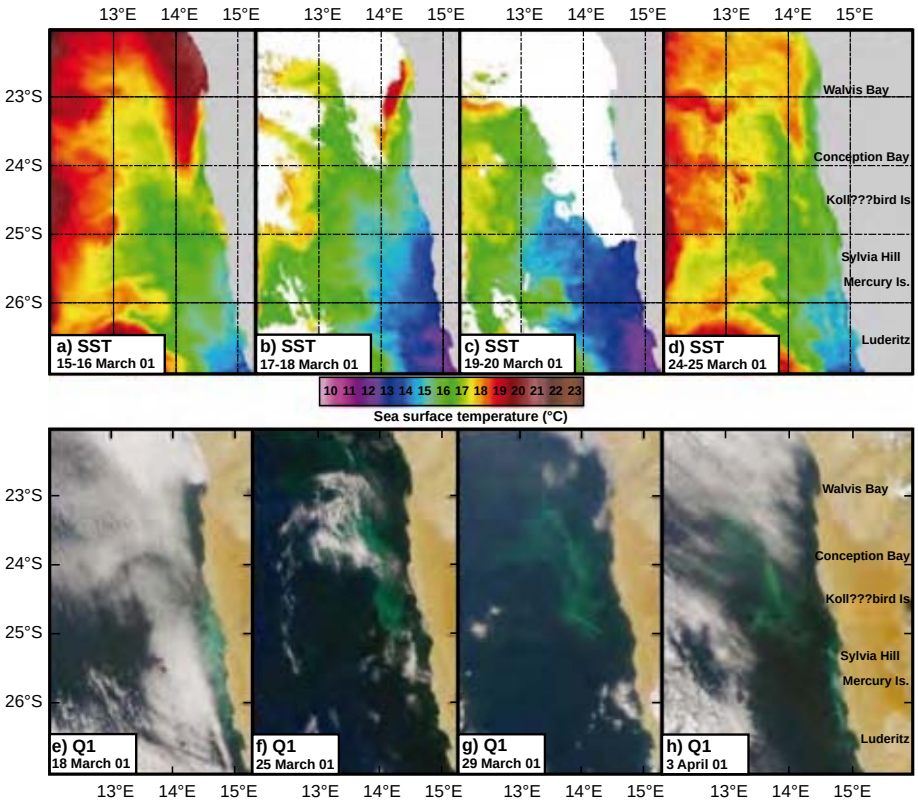

Figure 1. NOAA AVHRR false-colour SST and SeaWiFS quasi-true colour images (upper and lower panels respectively) for the region 12°-16°E; 22°-27°S during the period March-April 2001. Areas of milky turquoise colouration in the lower panel indicate high concentrations of suspended sulphur granules in surface waters (note that the individual images in the lower panel do not necessarily correspond to those in the upper panel).

Temperature and chlorophyll indices

Plots of satellite-derived indices of SST and near-surface chlorophyll in the southern Benguela over a number of years (Fig. 2) both clearly show the Cape Columbine and Cape Peninsula upwelling cells, the seasonality and synchronous nature of the upwelling at these two localities and the rapidly pulsating nature of the upwelling in the southern Benguela (the latter is in contrast to the northern Benguela where the indices have shown that the upwelling is more widespread and more perennial).

From this study, integrated SST, upwelling and chlorophyll indices were derived for the Cape Peninsula, St Helena Bay and Namaqua shelf areas, enabling temporal and spatial patterns in upwelling intensity at these locations to be more comprehensively quantified and compared than has previously been possible.

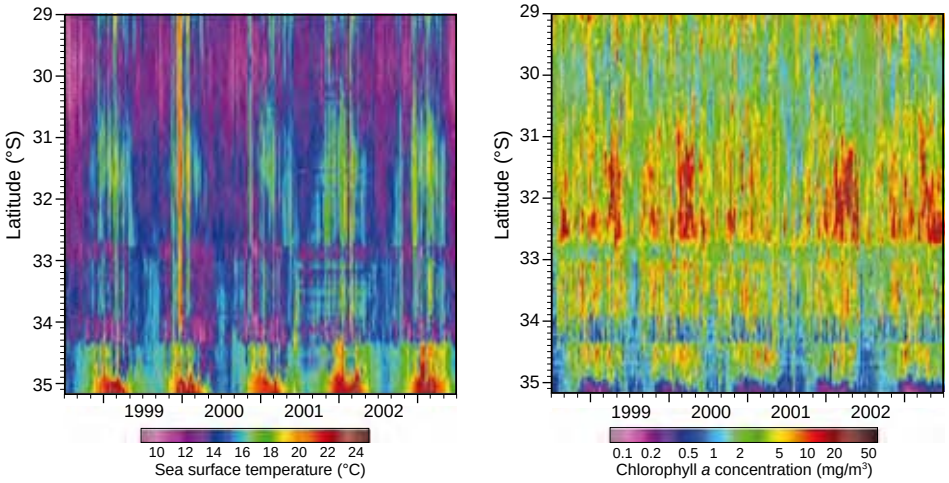

Figure 2. Hovmueller shelf width-averaged plots for the southern Benguela inner shelf (0-100 m) from 29.00°S to 35.18°S: (left) SST for July 1998 - June 2003 and (right) chlorophyll *a* concentration for July 1998 - June 2003.

Angola/Benguela frontal processes

The interannual variability of the seasonal warming in the northern Benguela caused by the intrusion of tropical water from the north is clearly shown in the decades-long SST time series in Figure 3. The images show that the extent of the warming is determined to some extent by the intensity of the upwelling off Namibia in summer, which means that satellite derived SST measurements along the Namibian coast can be used to track this seasonality. Latitudes of specific isotherms can easily be derived from such time series as environmental indicators, for use in further analysis.

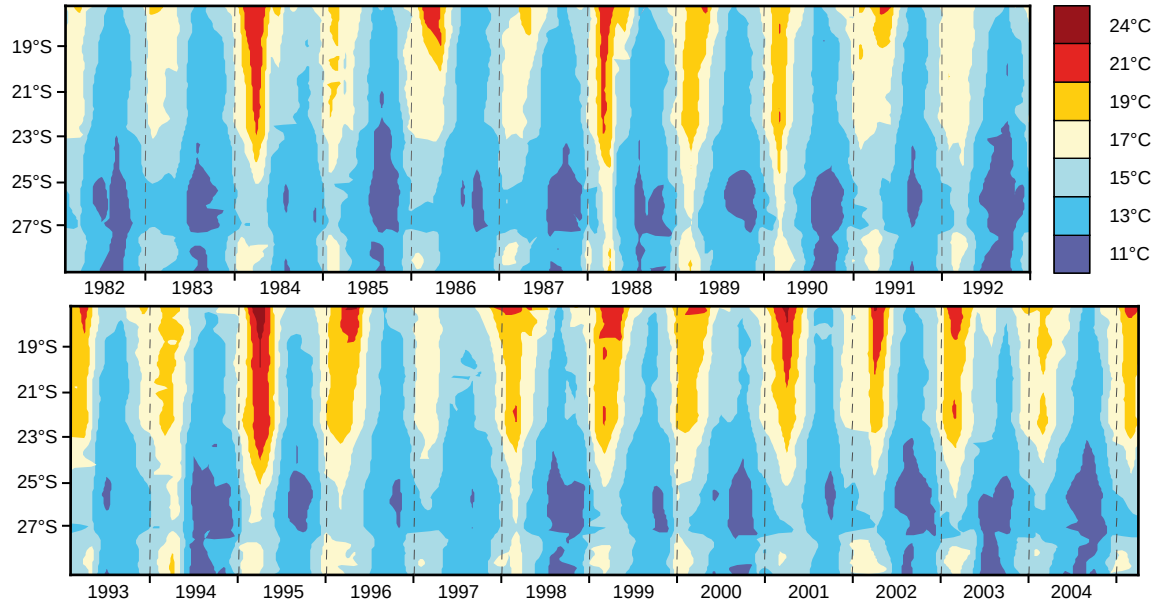

Figure 3. Satellite-derived sea surface temperatures along the Namibian coast; January 1982 - March 2005.

Variability of upwelling and ecological implications

A monthly time series of the mean SST over the continental shelf between Cape Point and the Cunene River from January 1986 to January 2000 has been calculated by averaging the SST between the coastline and the 500 m isobath (Fig. 4). This index highlights the main environmental events that have occurred over the last 15 years. On close examination it shows that during the major climatic events there is a tendency for the northern and southern Benguela to be out of phase. The cause for such a dipole structure remains unknown.

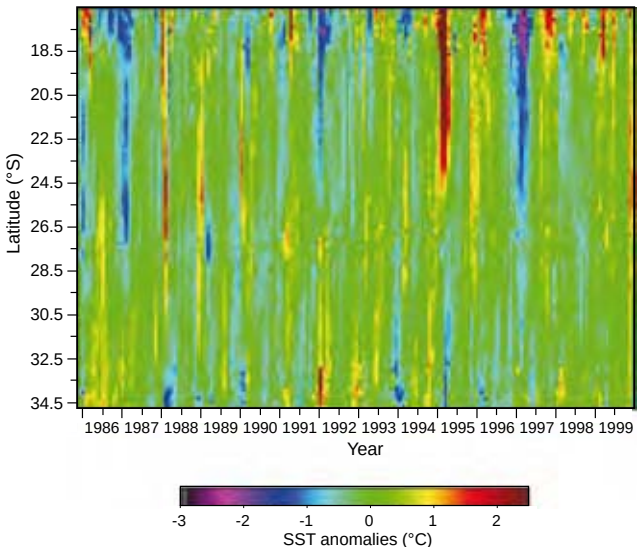

Figure 4. Hovmueller plot of monthly SST anomalies over the continental shelf from January 1986 to January 2000.

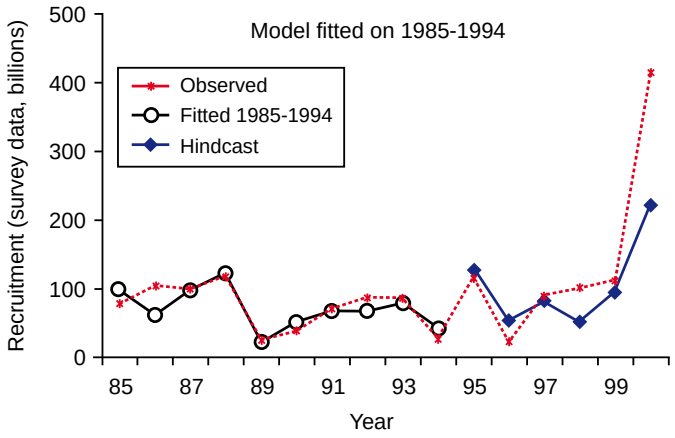

Figure 5. Observed and modelled anchovy recruitment time-series in the southern Benguela.

An empirical relationship between acoustic estimates of anchovy recruitment and two satellite-derived temperature-anomaly indices (surrogates for transport off the Cape Peninsula during December and upwelling intensity off the West Coast in January) has been developed as a predictor of anchovy recruitment strength, and tested on a subset of the data. The fit (Fig. 5) is encouraging, but needs to be tested over a longer time series.

Integrated chlorophyll index

SeaWiFS data were used to compute monthly mean chlorophyll distributions between 12 and 34°S to a defined offshore concentration limit (Fig. 6, left panel) on a temporal and spatial scale relevant to the dynamics of recruits of commercially exploited fish populations in the region. Seasonal and interannual patterns of chlorophyll concentration within the Benguela system between 1997 and 2002 derived from these averages are shown (Fig. 6, right panel).

Outputs

Data

A large volume of high-quality satellite data from this project has been archived on hard drives at UCT, backed up on hard drives at M&CM and NatMIRC.

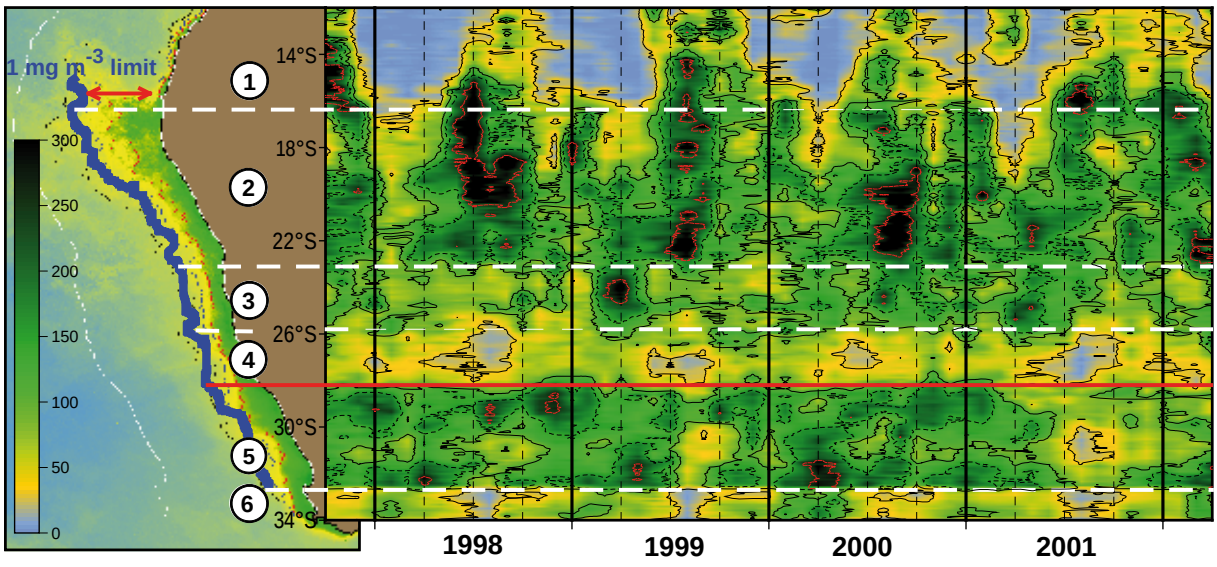

Figure 6. Monthly averages of chlorophyll *a* estimated from SeaWiFS data from October 1997 to March 2002.

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