OCEAN COLOUR OBSERVATION SYSTEMS FOR HARMFUL ALGAL BLOOMS IN THE BENGUELA

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The Benguela, one of the most productive upwelling systems in the global ocean, suffers from the frequent occurrence of a variety of harmful algal blooms (HABs). Ocean colour remote sensing has demonstrated considerable potential for the observation of HABs, particularly so in the Benguela where the very high biomass bloom events typical of the system provide a strong optical signal. Harmful impacts of HABs, most often composed of a variety of dinoflagellate species, are associated with either the toxicity of some species present in the algal assemblage, or the high biomass such blooms can achieve. Collapse of high biomass blooms through natural causes such as nutrient exhaustion can lead to hypoxic events and in extreme cases, the production of hydrogen sulphide, frequently causing extensive mortalities of marine organisms. Management of the ecosystem requires an ability to observe HABs in real-time, and a greater understanding of the variability of HABs as ecologically prominent phenomena - ocean colour based observing systems can make an important contribution to both research and operational goals.

The development of ocean colour-based observation systems for the detection and monitoring of such blooms in the Benguela, using data from both the Medium Resolution Imaging Spectrometer (MERIS) and the Moderate Resolution Imaging Spectrometer (MODIS), are discussed. HAB detection places rigorous demands on our understanding of causal processes; radiative transfer and empirical studies examining the potential and problems for the detection of algal community change are presented. Typical bloom events and current understanding of characteristics, cause and variability from both space-based and in situ data are used to better understand observing system requirements. Potential problems with the application of rigorous ocean colour techniques in optically complex coastal waters are highlighted, particularly the high levels of uncertainty currently associated with standard coastal ocean colour products. Major problems are associated with atmospheric correction schemes that may perform poorly in turbid, atmospherically complex coastal waters; and the similarly the sub-optimal performance of standard empirical in-water algorithms in such waters.

Example bloom events in the last five years are used to study the performance of both standard MERIS and MODIS products, and emerging generic and system-specific analytical and empirical algorithms for both biomass and algal assemblage determination. These include: an analytical reflectance inversion algorithm, allowing estimates of chlorophyll at high biomass and descriptors of algal size; regional empirical algorithms based on red wavelengths; fluorescence line height and quantum yield products; and spectral classification algorithms. Comparisons are made between the performance of these algorithm types and their potential application for both research and operational monitoring. An important aspect of the work is the validation of water-leaving radiance or reflectance data and geophysical products in the high biomass and spatially heterogeneous waters associated with algal blooms. Initial validation studies using bio-optical data from automated buoy measurements and dedicated field campaigns are presented.

Algorithm application is also discussed with regard to the development of integrated observation and forecasting systems: real-time bloom detection and tracking, and coupled ecological-hydrodynamic models. Prototype real-time observing systems are demonstrated as part of the Chlorophyll Globally-Integrated Network (ChloroGIN) system.