EO WATER QUALITY DATA OVER THE INTERNET

Aquatic Ecosystems from Space

Space-borne Earth Observation (EO) can offer a low-cost source of information in spatially extended areas of interest. A number of services have come online in recent years to facilitate access to EO data on aquatic ecosystems, providing raw data or derived products from operational ocean-observing instruments such as MODIS onboard AQUA (NASA) or MERIS onboard Envisat (ESA). This article highlights the benefits and discusses the limitations of space-borne EO for monitoring spatially extended aquatic ecosystems.

From a users' point-of-view, the decision to integrate EO data products into operational monitoring schemes has to be based on a thorough analysis of the actual requirements. Inherent limitations in product accuracy and availability mean EO methods are not typically used to replace in situ methods but rather act as a complementary source of information allowing these to be put into a wider context. In certain circumstances, however, EO may be the only available source of information. We here present selected online services, commercial as well as non-commercial, providing operational access to data products with direct relevance for water quality monitoring.

Benefits

Space-borne EO is an extremely valuable method of obtaining a synoptic overview on large areas of interest at comparably high spatial and temporal resolution (see Figures 1 and 2). In remote areas or in the absence of the technical or financial resources required for in situ sampling it may be the only available source of information. As regards aquatic ecosystems, a number of operational instruments such as MERIS (ESA) or MODIS (NASA) allow the determination of parameters with direct relevance to water quality in the topmost water layer, most importantly chlorophyll-a, suspended particles and water transparency, from measurements in the visible and near-infrared part of the spectrum, as well as sea-surface temperature (SST) from measurements in the thermal infrared. These parameters are globally available at spatial and temporal resolutions of typically 300-1000m and one to three days, respectively. They provide invaluable information on the surface dynamics of spatially extended aquatic ecosystems. A considerable number of programmes have been initiated by various space agencies to ensure the continuity of observing aquatic ecosystems from space. The International Ocean Colour Coordinating Group (IOCCG) provides further information under http://www.ioccg.org/.

Inherent Limitations

Information on parameters related to water quality are derived from multi-spectral measurements in the visible and near infrared. Only in this spectral range ('ocean colour') is the water transparent enough to see within the water body. The thickness of the water layer from which information can be inferred depends on the water transparency and is typically confined to a range between 0.1m and 10m. Measurements in the thermal infrared are used to derive the skin temperature of the sea surface, which is subsequently converted into the bulk temperature. Due to both the influence of the atmosphere interacting with the signal leaving the ocean surface, and the principally limited information content of multispectral measurements, the absolute accuracy of EO-derived parameters is usually inferior to that of direct sampling methods (see under 'Accuracy Considerations'). In the case of cloud cover the ocean is invisible from space in spectral range concerned and no product can be inferred.

Accuracy Considerations

The accuracy with which water-quality parameters can be inferred from space depends on a number of aspects, most importantly the actual atmospheric and sea-surface conditions, and the absolute and relative abundance of water constituents. The SST is the parameter that can be obtained with the best accuracy with absolute error of mostly +/-1Â°K. Here the biggest potential source of error is undetected, thin cirrus cloud. Parameters obtained from ocean colour (see under 'Benefits') can quite accurately be determined in the open ocean, where the ocean colour mainly depends on the amount of phytoplankton in the surface layer. In the case of a clear atmosphere and the absence of specular reflection of direct sunlight towards the satellite, error of +/-50% is mostly achieved. Considering the range of concentration of water constituents (e.g. between ca. 0.03 to 30mg m^{-3} for chloro-phyll-a in the open ocean), this is a good result and not too far from the accuracy of in situ sampling methods (typically ~20% error). In waters where several constituents contribute to ocean colour, such as in estuaries, water quality parameters are often impossible to derive with reasonable accuracy. Nevertheless, qualitative information such as the extension of river plumes can still provide local experts with very valuable information.

Practical Obstacles

In spite of the principle advantages of EO for monitoring spatially extended aquatic ecosystems, the number of especially non-scientific end users that have integrated EO products into their operational procedures is limited. There are two main reasons for this. Firstly, end users have in the past often been promised a degree of service reliability and product accuracy that could not be maintained in operational applications. These end users are now reluctant to consider using EO data products again. Secondly, experience has shown that even potential users with good knowledge of EO do not use it for their daily work because of the complexity involved in obtaining EO data products in the individually required specifications. To overcome the first obstacle it is mandatory that potential users are fully informed about the limitations of EO data products (see under 'Inherent limitations' and 'Accuracy Considerations'). To overcome the second obstacle a number of cost-efficient and user-friendly online services for ordering and retrieving have been established (see under 'Cost

Considerations' and 'SISCAL Access to EO data' below).

Cost Considerations

The cost of EO data products on water quality are generally low as compared to those derived, for example, from Synthetic Aperture Radar (SAR) data. The reason for this is that the required raw data is mostly made available free or at reproduction costs by the concerned space agencies. In addition, the amount of data processing involved is rather limited as compared to SAR data products. Services such as OceanColor (http://oceancolor.gsfc.nasa.gov/) or CoastWatch (http://coastwatch.noaa.gov/) publicly offer a range of standardised data products at no cost at all. Specialised services such as SISCAL offer products and services tailored to individual user needs. Such services are often operated by value-adding companies, mostly SMEs, and need to recover the operational costs. However, charges here are also comparably low due to the fact that the development of such services has often partly or entirely been financed through public funding and raw data is available free of charge. Table 1 gives a non-exhaustive overview of selected online services from which water-quality parameters may be obtained.

SISCAL Access to EO data

One example of a service that aims to combine user friendliness with the ability to meet individual user demands is the on-line service SISCAL (http://www.siscal.net/),developed with support of the European Commission between 2001 and 2004 as a co-operation between ten partners from five countries, including four end users representing public authorities with responsibilities ranging from regional to local scales. By providing a simple interface hiding the complexity in product generation, SISCAL makes EO data products readily accessible to non-expert users. It offers individual service tailoring in terms of area of interest, geographic projection, data formats and integration of user-provided local or experimental algorithms (Figure 3). A preconfigured GIS-tool based on ESRI ArcGIS allows combining SISCAL products with locally available geo-information. Other functions include product archiving and searching, data analysis, and the generation of animations, Level-3 (temporally averaged) products and maps (Figure 4).

Fields of Application

SISCAL serves diverse applications, such as aquatic environment monitoring, studying long-term trends, optimising in situ sampling, acting as operational algorithm test-bed, distributing geo-spatial data within dedicated user networks, and granting public access to environmental information. SISCAL customers come mostly from the public sector, such as environmental agencies, oceanographic institutes or public authorities acting at regional or sub-regional level. Potential commercial applications include fisheries, aquaculture, tourism and offshore industries. SISCAL products have recently been integrated into the Israel Marine Data Center (ISRAMAR, http://isramar.ocean.org.il/) operated by Israel Oceanographic and Limnological Research Ltd (IOLR, http://www.ocean.org.il/). ISRAMAR is the national repository and dissemination facility for oceanographic data. By applying user-specific algorithms calibrated to local atmospheric conditions SISCAL SST products derived for the Dead Sea and the Sea of Galilee are more accurate than standard products.

Conclusions

With the recent advent of internet-based services, EO derived data products on parameters relating to water quality such as SST, chlorophyll-a, suspended particles or water transparency have become increasingly accessible in comparatively high temporal and spatial resolution and at reasonable cost. Public authorities or private companies with a need for information on the spatial and temporal distribution of water-quality parameters should consider the integration of EO-based services into their operational procedures as a complementary source of information.