Low-cost marine water-quality monitoring

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Commercial digital cameras can detect constituent concentrations from in situ ocean-color measurements.

Environmental and climate-change studies as well as coastal-zone management require constant monitoring of marine water quality. Chlorophyll concentration is an important parameter, since it can signify the risk of harmful algal blooms. As an index of carbon-consuming phytoplankton, it also plays a major part in ocean carbon-flux calculations and, hence, in climate research. Yellow-substance (also known as colored dissolved organic matter) observations reveal the dispersal of fresh water in the ocean, which can be used in coastal-pollution assessments (for example, if a river is a polluting source or if a waste-effluent outfall is located along the adjacent coast).

Satellite remote sensing is one way of gathering water-quality data, but in regions where satellite spatial resolution is too low, shallow water and land borders can contaminate the image and in situ or airborne-mounted systems must be employed. Traditionally, multispectral narrow-band radiometers are used to measure optical properties of natural waters but these are costly. We have used low-cost standard digital cameras as simple three-band radiometers. Using a digital camera as an in situ optical instrument is a novel application of a known technique. Most existing remote-sensing algorithms for water-quality assessment use the visible spectrum. Light that wells up from below the surface contains information about water composition. It is captured by attaching a tube breaking the water surface to the camera lens. Another approach is to use a waterproof camera or mount the camera in a waterproof housing.

Remote-sensing algorithms for water-quality parameters are commonly based on band ratios of reflectance. A blue/green reflectance ratio decreases with increasing chlorophyll concentration in a negative-power fashion, while a red/blue reflectance ratio is proportional with yellow substance. An imaging camera’s response to light in the red, green, and blue bands can be quantified by the red, green, and blue (RGB) digital values of the image, if intensity and white-balance setting are kept constant. We tested relations between the red/blue RGB ratio (R/B) and yellow-substance absorption, and between the blue/green RGB ratio (B/G) and chlorophyll concentration.

We used the Nikon Coolpix 885 (see Figure 1) and the SeaLife ECOshot as in situ optical instruments during numerous surveys in Galway Bay (Ireland). We used the Coolpix 885 to take digital images of subsurface light leaving the water and collected surface water samples at the same time (see Figure 2). We surveyed at different times of the year and under changing weather conditions. As a result, the lighting environment varied greatly and included extremely low light levels. We took simultaneous measurements with a Bangor ocean-color sensor (OCS), an in situ irradiance meter designed for ocean-color observations. In one survey, we took underwater pictures with the...
Figure 2. Digital images of subsurface water-leaving light, taken with
the in situ Coolpix 885 in Galway Bay (Ireland) on 2 November 2004,
(a) inside and (b) outside the River Corrib plume. R/B and B/G: Respec-
tive red/blue and blue/green RGB ratios. ah(440): Yellow-substance ab-
sorption. Chl: Chlorophyll concentration.

Figure 3. Images inside the UV-1601 spectrophotometer of a beam of
monochromatic light (taken with the Coolpix 885) and the spectrometer
output wavelengths set at (a) 470, (b) 550, and (c) 660nm.

ECOshot. We also tested the Coolpix 885 in clearer waters of the
Celtic Sea and the North East Atlantic.

The in situ measurements show an approximately 1:1 relation
between RGB values and digital counts in the respective red,
green, and cyan channels of the OCS.3 We also measured
the response spectra of the digital cameras in a UV-1601®
double-
beam spectrophotometer. Both cameras fit in the closed spec-
trophotometer and we took pictures of one beam projected onto
white paper for wavelengths 10nm apart (see Figure 3). We de-
derived RGB values of the image of the projected beam and quan-
tified the response of each individual band to light of a certain
wavelength (see Figure 4).

We found relations between R/B and yellow-substance ab-
sorption, and between B/G and chlorophyll concentration, simi-
lar in shape and precision to known remote-sensing relations
(see Figure 5). The relationships are survey dependent, corre-
sponding to properties of the water body (and not to lighting
conditions) during a survey. The yellow-substance-to-R/B rela-
tion changes with plume depth, while the chlorophyll-to-B/G
relation depends on the level of covariance between yellow sub-
stance and chlorophyll.3 Differences between the Coolpix 885
and the ECOshot are minor and can be partly explained by their
response spectra.3 We used the negative linearity between yel-
low substance and salinity to map the River Corrib plume in Gal-
way Bay.1 The range of observed colors is considerably smaller
in the North Atlantic than in Galway Bay, but biological patterns
over the Porcupine Bank can be recognized.3 A significant power
relation between B/G and the satellite OCS-derived chlorophyll
a confirms our finding3 and shows the camera’s potential in
oceanic waters.

In summary, a conventional digital camera can be used as a
robust, small, lightweight, user-friendly, and inexpensive three-
band radiometer. The broad camera bands do not appear to hurt

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our ability to quantify ocean color. The auto-exposure feature of the digital camera makes adjusting to varying light levels very easy. Potential future applications could be time-series measurements using a timer-operated digital camera mounted on a buoy or continuous measurements using a video camera. We are also exploring possibilities for monitoring more aquatic components, such as mineral-suspended sediments, using the R/G ratio.²

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David Bowers is a reader in physical oceanography. His research interests are in the dynamics of estuaries and coastal waters and, in particular, how these may be studied through their optical properties, using both direct and remote sensing.

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References


Damien Dailloux is a coastal engineer. His activities focus on coastal video-monitoring techniques. This includes development, installation, and maintenance of coastal-video systems applied to beach morphodynamics, river-plume dynamics, wave-characteristics measurements, and surface-current velocity measurements from particle-image velocimetry techniques.

Denis Morichon is an assistant professor in the civil engineering school. His research activities focus on wave-sediment interaction. This includes numerical modeling of wave-induced sediment transport in the swash zone, wave generation by landslides, and video monitoring of coastal hydrodynamics.