MONOCLE
Multiscale Observation Networks for Optical monitoring of Coastal waters, Lakes and Estuaries

January 2019

# Reflectance: water colour

## Why should we measure reflectance?

The colour of a natural body of water can tell us a lot about its biological and chemical properties. This is why Earth-observing satellites equipped with sensitive cameras observe the reflectance of the world ocean and all inland waterbodies on a near-daily basis. By interpreting water colour, we can derive the abundance of algae or the amount of sediment being transported in water, because each of these components has unique optical properties.

Satellites observe the Earth through the atmosphere. Separating the colour of the Earth's surface from the effects of the atmosphere is one of the major challenges of satellite observation of water. Therefore, it is important to collect sufficient ground-truth measurements of diversely coloured waterbodies. These can then be used to ensure that the water colour data derived from the satellite image are correct under a wide range of conditions. In addition, they are used to ensure that the satellite sensors themselves are performing as they should.

## Where should we measure?


The best locations for the measurement are in open terrain (away from trees and buildings or anything that could block a clear view of the sky around) and where the water is optically deep – this means that the bottom does not influence the light that is measured. Jetties and boats are often ideal measurement locations when using hand-held sensors. Automated sensors are also being developed in MONOCLE to make it easy to use offshore poles, lighthouses, ships and even buoys.

## How do we measure reflectance?

To observe the 'true' colour of the water (the 'reflectance') we need to correct for the colour of the light reaching it from the sky. The downward light can be anything from grey to blue or red depending on cloudiness and the elevation of the sun. To correct for the variable colour and intensity of downward light, it needs to be measured at the same time as the reflected light. This is done with radiometers. Radiometers can be used under or above the water surface, or even at great distance such as on satellites, which may be a far as 800 kilometres overhead.

A radiometer pointed at the water from above the surface will record the upward radiance, which includes light reflected directly off the water surface. It is important to point the radiometer away from reflected sunlight ('glint') and slightly forward (up to 40 degrees) to avoid interference with the measurement. A second measurement pointed at the sky under the same forward angles is needed to correct for the remaining surface-reflected light. After this correction is made, the 'water-leaving radiance' is divided by the downward irradiance coming from the sky overhead. This is the 'water-leaving reflectance'.

## When can we measure?

Sufficient sunlight needs to enter the water to be able to measure reflectance. The daily period during which the sun is high enough in the sky (at least 30 degrees from the horizon) changes with season, and depends on your latitude (Fig. 1). At the equator this changes very little during the year with 8 hours per day of suitable observations. However, at higher latitudes, the season for *in situ* reflectance measurements is much shorter, making automated measurement systems which can capture these moments even more useful.


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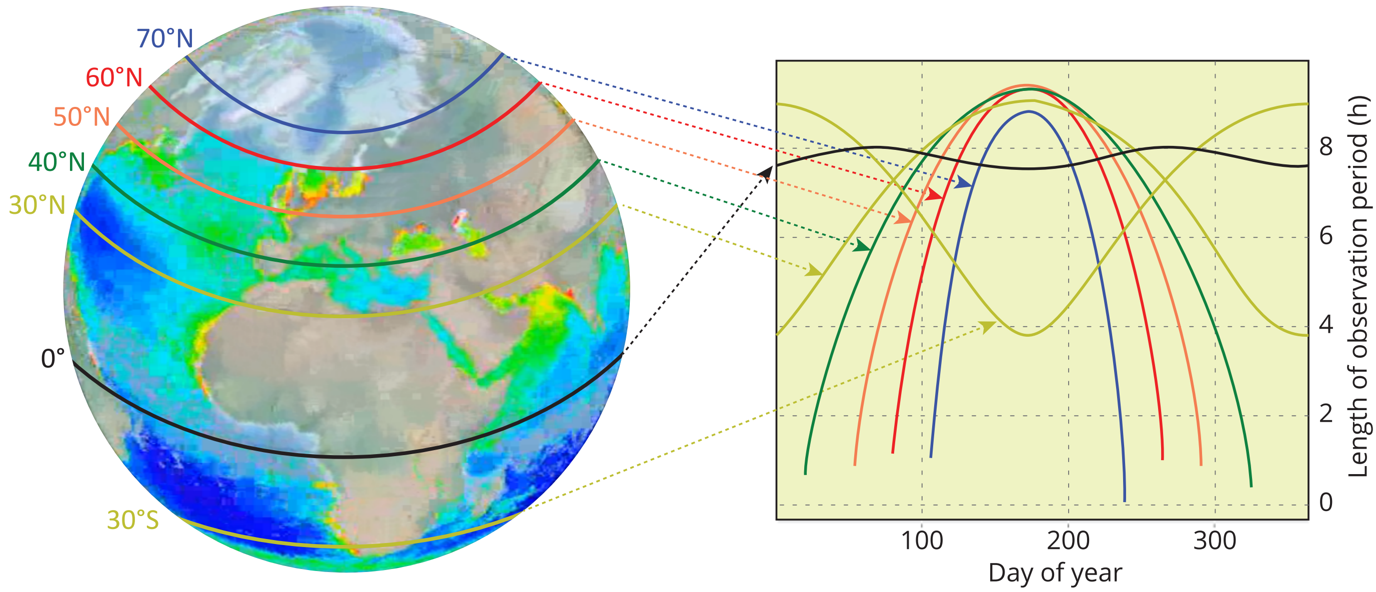


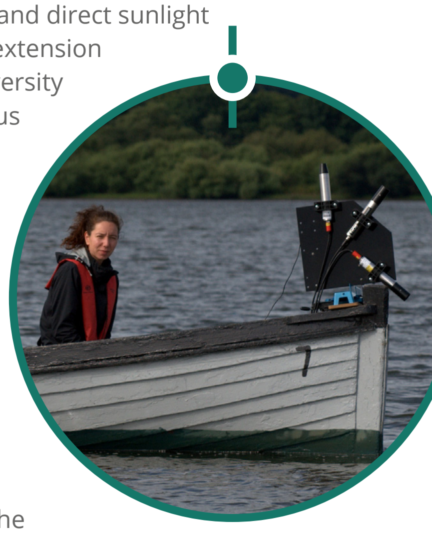

*Figure 1. The seasonal (width of curve) and daily (height of curve) window for successful in situ reflectance measurements, plotted for several latitudes.*

## What is expected of a sensor?

Under most common conditions, the water leaving reflectance is influenced by detectable water optically active substances, typically in a wavelength range roughly between 380 nm (ultraviolet, deep blue) and 780 nm (infra-red). The optical features we want to be able to detect (such as pigment absorption peaks indicating algal presence) have a typical minimal width of 10–20 nm. Since the water leaving radiance is relatively weak, the sensor needs to have a relatively high sensitivity. Furthermore, using multiple radiometers in combination, or using them for satellite validation, poses quite strict requirements on sensor characterisation and (inter) calibration. Due to changing light and surface conditions (waves), a reflectance measurement should be taken quickly (less than one second). Series of measurements can then be used to observe water quality development at small intervals. They can also be used to observe what a satellite should measure at the time of overpass with a very short time difference. Shipborne and hand-held sensors are suitable for this purpose combined with fixed position autonomous sensors at locations that are more difficult to visit frequently.

## What is MONOCLE doing for reflectance measurements?

A lot! The project is developing a number of sensor systems and deployment methods. These include a modular version of the WISP (by Water Insight), a hyperspectral version of a pyranometer to measure diffuse (scattered by clouds) and direct sunlight (by Peak Design), a low-cost extension for smartphones (iSPEX, University of Leiden) and an autonomous solar-tracking platform for moving platforms (by Plymouth Marine Laboratory). We also work on producing reflectance measurements from remotely piloted aerial systems (drones). To complement innovation in sensor systems, we also develop protocols for field-based calibration to reduce the cost of sensor maintenance.



**MONOCLE is an EU-funded research project developing water quality observation solutions using satellites, buoys, ships, and hand-held devices. These range from highly accurate automated systems to low-cost sensor solutions that can be built and operated by citizens.**

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This factsheet was produced by PML, Water Insight, Peak Design and University of Leiden.
Check out the work they and other organisations are doing in MONOCLE at www.monocle-h2020.eu.

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