ID32- WATER QUALITY MONITORING PROGRAM THROUGH THE KDUSTICK, A LOW-COST AND DO-IT-YOURSELF INSTRUMENT CONNECTED BY THE INTERNET OF THINGS

CARLOS RODERO[1], RAUL BARDAJI[2], JOAQUIN SALVADOR[1], ESTRELLA OLMEDO[1], JAUME PIERA[1].

1 Institute of Marine Sciences (ICM - CSIC), Passeig Marítim de la Barceloneta 37-49, E-08003 Barcelona (Spain), +34 93 230 95 00, +34 93 230 95 55, rodero@icm.csic.es

2 Marine Technology Unit (UTM - CSIC), Passeig Marítim de la Barceloneta 37-49, E-08003 Barcelona (Spain), +34 93 230 95 00, +34 93 230 95 55, bardaji@utm.csic.es

Abstract

Monitoring water transparency provides an indicator of the environmental status of the water body. One parameter to estimate the water transparency is the light diffuse attenuation coefficient (Kd).

In the framework of the H2020 project MONOCLE (Multiscale Observation Networks for Optical monitoring of Coastal waters, Lakes and Estuaries), we have developed an improved version of the KdUINO (Bardaji et al., 2016) consisting of a moored instrument used to assess water transparency. This new version, the KduSTICK, estimates Kd near the surface in real-time following these specifications: cost-effective, portable, real-time monitoring and easy to use with minimal training.

This instrument transmits data by using the Internet of Things (IoT) networks. In particular, our research group participates in the initiative "The Things Network" (TTN), an IoT network based on LoRaWAN.

This device is easy to deploy and maintain, and it is suitable for citizen-science based water quality monitoring programs.

Keywords

Water quality, Do-It-Yourself, Citizen Science, Internet of Things

INTRODUCTION

The studies of light propagation and light field characteristics are crucial for understanding many physical and biological processes in the water bodies, depending on solar radiation[1], such as phytoplankton dynamics and surface bloom [2] or eutrophication [3]. This radiation at the sea surface is conventionally measured as downward planar irradiance at specific wavelengths (λ), Ed(λ). The attenuation of this quantity with depth (z) can be described by the diffuse attenuation coefficient Kd(z,λ)[4]. This parameter is of particular interest in water quality monitoring programs because it represents a suitable proxy of water transparency [5], and it is related to light penetration and availability in aquatic systems [4] [6]. It is especially relevant in coastal areas and lakes strongly affected by human activities.

Satellite-based ocean colour sensors have been used to map optical properties of the ocean such as Kd(z, λ). Approximately 90% of the diffuse reflected light from a water body comes from a surface layer of water within a depth of 1/Kd [7]. Therefore, Kd is an essential parameter for remote sensing reflectance of ocean colour from satellites. With an increase in remote sensing data availability over the past decade, there has been a rise in the in situ data available for calibration and validation of satellite measurements [8]. However, the current satellite measurements for monitoring coastal and inland waters are still evolving and remain challenging because of the spatial scales that satellite measurements represent [9]. To improve data coverage in these zones, in situ irradiance measurements are still required.

Furthermore, growing worldwide needs to explore cost-effective data acquisition to generate knowledge for sustainable natural resource management. This need to develop novel approaches for monitoring environmental data is reflected in citizen science's recent growing attention [10]. One of these in-situ sensor systems is the low cost and DIY (Do-It-Yourself) moored system KdUINO, which allows measuring the diffuse attenuation coefficient parameter (Kd) [11].

The participation of citizen scientists in water quality monitoring complements traditional monitoring methods. Besides, it has other potential advantages such as lowering monitoring costs, significantly increasing data coverage, increasing social capital, enhancing support for decision-making, and enhancing the potential for knowledge co-creation [12].

INSTRUMENT DESIGN AND CONNECTIVITY

Within the framework of H2020 MONOCLE project, our group is redesigning the KdUINO to retrieve Kd from near-surface measurements. The new KdUINO, called KdUSTICK, is a watertight transparent tube of 1.5 m. of height and a diameter of 4 cm. Some light measurement sensors are located at different positions inside the tube. The tube also contains a low-cost and low-power microcontroller with integrated Wi-Fi and Bluetooth to control the sensors. The microcontroller receives the data from the sensors and stores it in a memory card. The KdUSTICK is placed vertically in the water column, and it floats like a buoy. Most of the tube is submerged, but there is a small part that remains outside the water. The sensors can measure light at different depths because of the transparency of the tube.

To estimate Kd, the KduSTICK measures the light intensity in the PAR (Photosynthetically Active Radiation) band at several depths in the water column. Using the linear regression of such measurements, Kd is retrieved applying the Beer-Lambert law on the light measurements (Fig. 1).

The KdUSTICK transmit data using the Internet of Things (IoT) networks, such as LoRaWan and Sigfox [13]. In particular, our research group cooperate with the initiative "The Things Network" (TTN). This community network allows devices to connect to a decentralized open-source network to exchange data between applications based on LoRaWAN.

The new KdUINO instrument has been designed to connect to TTN nodes, bringing public coverage over the coast where the TTN is (Fig. 2).

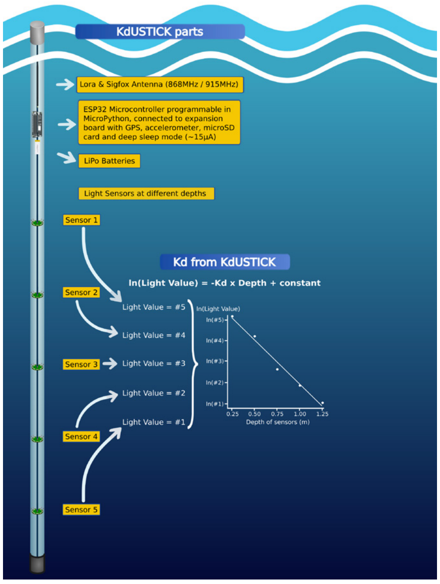

Fig. 1. Schematic of the KdUSTICK design, illustrating all its parts and demonstrating how it calculates Kd.

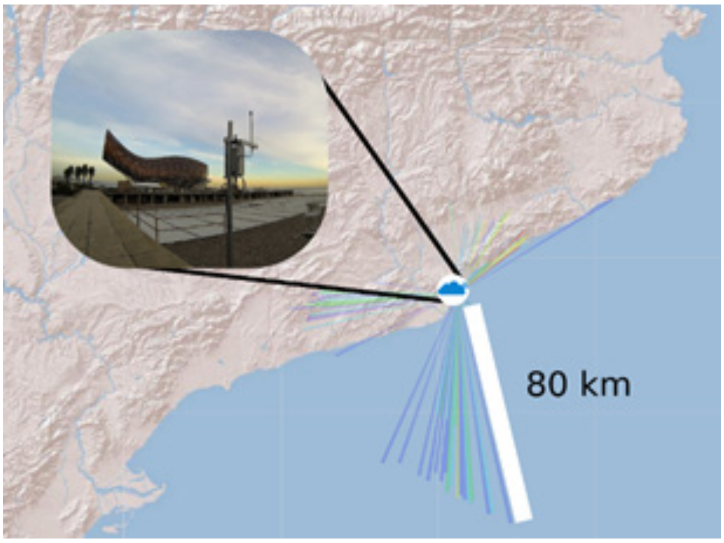

Fig. 2. The instrument transmits data using the Internet of Things networks. 80 km towards the Mediterranean Sea are covered with the TTN antenna installed at the Institute of Marine Sciences.

ACKNOWLEDGEMENTS

The work of Raul Bardaji is supported by the CSIC Intramural Project EMSO – Laboratorios Submarinos Profundos.

The work of Carlos Rodero is supported by the H2020 Project MONOCLE (grant agreement No 776480).

REFERENCES

[1] Mobley, C.D.; Chai, F.; Xiu, P.; Sundman, L.K. Impact of improved light calculations on predicted phytoplankton growth and heating in an idealized upwelling-downwelling channel geometry. Journal of Geophysical Research: Oceans 2015,120, 875–892.

[2] Horion, S.; Bergamino, N.; Stenuite, S.; Descy, J.P.; Plisnier, P.D.; Loiselle, S.A.; Cornet, Y. Optimize dextraction of daily bio-optical time series derived from MODIS/Aqua imagery for Lake Tanganyika, Africa.Remote Sensing of Environment 2010, 114, 781–791.

[3] Cairo, C.T.; Barbosa, C.C.F.; de Moraes Novo, E.M.L.; do Carmo Calijuri, M. Spatial and seasonal variation in diffuse attenuation coefficients of downward irradiance at Ibitinga Reservoir, São Paulo, Brazil.Hydrobiologia 2017, 784, 265–282.

[4] Mobley, C.D. Light and water: radiative transfer in natural waters; Academic press., 1994.

[5] Sarangi, R.; Chauhan, P.; Nayak, S. Vertical diffuse attenuation coefficient (Kd) based optical classification of IRS-P3 MOS-B satellite ocean colour data. Journal of Earth System Science 2002, 111, 237–245.

[6] Wang, M.; Son, S.; Harding Jr, L.W. Retrieval of diffuse attenuation coefficient in the Chesapeake Bay and turbid ocean regions for satellite ocean color applications. Journal of Geophysical Research: Oceans 2009, 114.

[7] Lee, Z.; Carder, K.L.; Arnone, R.A. Deriving inherent optical properties from water color: a multiband quasi-analytical algorithm for optically deep waters. Applied optics 2002, 41, 5755–5772.

[8] Topp, S.N.; Pavelsky, T.M.; Jensen, D.; Simard, M.; Ross, M.R. Research trends in the use of remote sensing for inland water quality science: Moving towards multidisciplinary applications. Water 2020, 12, 169.

[9] Tyler, A.N.; Hunter, P.D.; Spyrakos, E.; Groom, S.; Constantinescu, A.M.; Kitchen, J. Developments in Earth observation for the assessment and monitoring of inland, transitional, coastal and shelf-sea waters. Science of the Total Environment 2016, 572, 1307–1321.

[10] Njue, N.; Kroese, J.S.; Gräf, J.; Jacobs, S.; Weeser, B.; Breuer, L.; Rufino, M. Citizen science in hydrological monitoring and ecosystem services management: State of the art and future prospects. Science of the Total Environment 2019, 693, 133531.

[11] Bardaji, R.; Sánchez, A.M.; Simon, C.; Wernand, M.R.; Piera, J. Estimating the underwater diffuse attenuation coefficient with a low-cost instrument: The KdUINO DIY buoy. Sensors 2016, 16, 373.

[12] Ho, S.Y.F.; Xu, S.J.; Lee, F.W.F. Citizen science: An alternative way for water monitoring in Hong Kong. Plos one 2020, 15, e02383.

[13] CSIC (2019, Feb 22). "Internet of Things for the study of the marine ecosystem", Consejo Superior de Investigaciones Científicas, last accessed 2021, 29 April. https://rdcsic.dicat.csic.es/en/recursos-naturales-2/121-projects/488-internet-of-things-for-the-study-of-the-marine-ecosystem