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WATERHYPERNET: Automated in situ measurements of hyperspectral water reflectance for satellite validation ... and more

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Abstract – Spaceborne optical remote sensing is routinely used for monitoring of water quality in coastal and inland waters via parameters such as phytoplankton pigments (chlorophyll a, phycocyanin, etc.) and suspended particulate matter. The quality of end-user products depends strongly on intermediate processing, particularly atmospheric correction and associated sunglint and adjacency corrections. In situ measurements of water reflectance are needed to validate the satellite data products. Building on experience gained from the multispectral AERONET-OC network, the WATERHYPERNET is being set up as an international network of sites running automated systems of pointable hyperspectral radiometers. An overview is presented of the WATERHYPERNET network, including a summary of hardware, data acquisition and processing and validation sites. Examples are provided of satellite validation applications. While satellite validation has been the primary motivation for development of this network, the availability of high frequency and long-term hyperspectral reflectance data is also stimulating spin-off applications, such as phytoplankton monitoring.

Keywords: ocean colour, satellite validation, phytoplankton, hyperspectral reflectance.

1. INTRODUCTION

Spaceborne optical remote sensing from daily 100-1000m resolution "ocean colour" missions such as MODIS, VIIRS and Sentinel-3/OLCI provides operational data to end-users for applications such as coastal water quality management (eutrophication, sediment transport, etc.). 10-100m resolution missions such as Landsat-8 and Sentinel-2 have also become popular tools for coastal and inland water monitoring. 1-10m resolution missions, including cubesat constellations such as Planetscope Doves, are now emerging (Vanhellemont, 2019) and offering new opportunities for applications inside ports and small lakes and for monitoring coastal operations (construction, dredging/disposal)

To ensure that the products from all these satellite missions can be trusted by end-users, and particularly to identify any atmospheric correction errors, in situ measurements of water reflectance are needed to validate the satellite data products. Building on experience from the multispectral AERONET-OC network (Zibordi et al, 2009), WATERHYPERNET is setting up an international network of sites running automated systems of pointable hyperspectral radiometers. WATERHYPERNET will thus provide water reflectance validation data at hyperspectral resolution every day for sites with diverse aquatic and atmospheric conditions.

2. HARDWARE and DATA PROCESSING

WATERHYPERNET hardware currently consists of two systems: a) the PANTHYR system based on the mature TRIOS/RAMSES radiometer, and b) the HYPSTAR® system based on a newly-designed radiometer.

The PANTHYR system, shown in Figure 1a, is described in detail by (Vansteenwegen et al, 2019) and consists of two TRIOS/RAMSES radiometers (one irradiance, one radiance; 400-900nm at 10nm FWHM) with an external camera mounted on a FLIR PTU-48E pan-tilt unit controlled by a single-board Beaglebone Black computer and associated custom-built electronics.

The HYPSTAR® system, shown in Figure 1b, consists of a newly-designed hyperspectral radiometer (380-1020nm at 3nm FWHM) with integrated radiance and irradiance fore-optics and embedded RGB camera, mounted on a Bowler Rx pan-tilt unit and controlled by a rugged PC.

Both systems include auxiliary sensors and site-dependent power supplies (grid, solar panels, batteries, etc.) and data transmission hardware (cabled Internet, wifi, 4G, etc.).

Both systems acquire data typically every 20 minutes during daylight following an abovewater radiometry acquisition protocol based on (Mobley et al, 1999). Measurements are acquired at both 90° and 135° relative azimuth to sun and potentially both left and right of sun, when permitted by the local mounting structure and its shadows/reflections. Data is transmitted to land in near real time for automated, centralised processing and quality control. Extension of the processing to generate uncertainty estimates for each data value is in progress following the work of the FRM4SOC project (Banks et al, 2020; Ruddick et al 2019). A data portal is under development to distribute data publicly to users such as satellite mission validation entities and developers of atmospheric correction algorithms.

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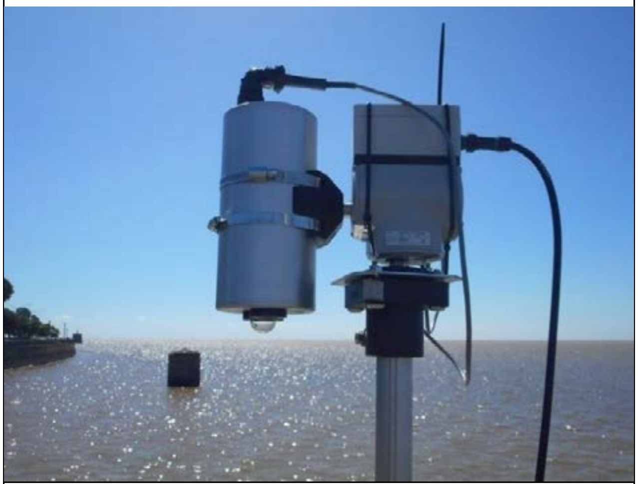

Figure 1. (a-top) PANTHYR radiometer system, (b-bottom) HYPSTAR® radiometer system. Cable tie spikes are used for bird avoidance.

3. VALIDATION SITES

PANTHYR and/or HYPSTAR® systems are currently running at 7 locations and are planned for 5 further locations in 2022 – see Table 1.

Table 1. WATERHYPERNET sites running (top 7) or planned in late 2022/early 2023 (bottom 5). System: P=PANTHYR, H=HYPSTAR; PI= Principal Investigator.

System	Location	PI
P,H	Aqua Alta, near Venice, Adriatic Sea, IT	CNR
P,H	Blankaart Reservoir, BE	RBINS
P	RT1, near Oostende, North Sea, BE	VLIZ
H	Etang de Berre, FR	LOV
H	Le Verdun, Gironde Estuary, FR	LOV
H	Near Buenos Aires, La Plata Estuary, ARG	IAFE
H	Lake Garda, IT	CNR
2022/23: P+H	Thornton Bank, North Sea, BE	RBINS
2022/23: P+H	Near Zeebrugge, North Sea, BE	RBINS
2022/23: H	Chascomus Lake, ARG	IAFE
2022/23: H	Lampedusa, Mediterranean, IT	CNR
2022/23: H	MESURO, Rhône plume, FR	LOV

4. CONCLUSIONS

Hyperspectral reflectance data from the PANTHYR system has already proven useful for validation of Sentinel-3/OLCI (Vanhellemont and Ruddick, 2021), Sentinel-2, Landsat-8 and Planetscope Doves (Vanhellemont, 2020) and PRISMA (Giardino et al, 2020). High quality data is now emerging also from the HYPSTAR® systems and the first matchups with satellite data are being analysed. The user need for hyperspectral water reflectance data is clear and growing stronger every year, with the existing satellite missions being joined by the new generations of cubesat constellations and hyperspectral satellite missions. The WATERHYPERNET has been developed to meet this need and the PANTHYR and HYPSTAR® systems and associated processing chains are now approaching maturity for routine operations to start in 2022 and 2023 respectively.

However, the utility of these systems is not limited to the application of satellite validation. A first application for phytoplankton species monitoring has also been demonstrated (Lavigne et al, 2022).

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REFERENCES

Banks, A. C. et al. Fiducial Reference Measurements for Satellite Ocean Colour (FRM4SOC). Remote Sens. 12, 1322 (2020).

Giardino, C. et al. First Evaluation of PRISMA Level 1 Data for Water Applications. Sensors 20, 4553 (2020).

Lavigne, H. et al. Monitoring of high biomass Phaeocystis globosa blooms in the Southern North Sea by in situ and future spaceborne hyperspectral radiometry. Rem Sens Env, 282, p.113270. DOI: https://doi.org/10.1016/j.rse.2022.113270 (2022).

Mobley, C. D. Estimation of the remote-sensing reflectance from above-surface measurements. Appl. Opt. 38, 7442–7455 (1999).

Ruddick, K. et al. A Review of Protocols for Fiducial Reference Measurements of Water-Leaving Radiance for Validation of Satellite Remote-Sensing Data over Water. Remote Sens. 11, 2198 (2019).

Vansteenwegen, D. et al. The pan-and-tilt hyperspectral radiometer system (PANTHYR) for autonomous satellite validation measurements. Remote Sens. 11, 1360 (2019).

Vanhellemont Q. Daily metre-scale mapping of water turbidity using CubeSat imagery. Optics Express, Vol. Vol. 27 Issue 20 pp. A1372–A1399 (2019).

Vanhellemont, Q. Sensitivity analysis of the dark spectrum fitting atmospheric correction for metre- and decametre-scale satellite imagery using autonomous hyperspectral radiometry. Opt. Express 28, 29948–29965 (2020).

Vanhellemont Q. & Ruddick K. Atmospheric correction of Sentinel-3/OLCI data. Rem Sens Env, 256, p. 112284. DOI: https://doi.org/10.1016/j.rse.2021.112284 (2021).

Zibordi, G. et al. AERONET-OC: A network for the validation of ocean color primary product. J. Atmos. Ocean. Techn. 26, 1634–1651 (2009).