From catchment to sea: Changes in particles characteristics using novel in situ and space technologies (Ref IAP2-18-73)

University of Stirling, Biological and Environmental Sciences
In partnership with Centre for Ecology & Hydrology

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Key Words

Overview

The Earth’s surface waters are a fundamental resource and encompass a broad range of ecosystems that are core to global biogeochemical cycling and food and energy production (Tyler et al. 2016). River-sea systems comprise river catchments, estuaries, lagoons and near-shore marine environments and are important interfaces between continents and seas. Processes in these systems influence the flux of particulate and dissolved materials from the catchment to the sea. River-sea systems provide ecosystem services that are fundamental to societal wellbeing. Nevertheless, rivers and seas have been modified progressively over the years with environmental consequences, which are cumulative and pervasive and can lead to extreme impactful events including drought and flood. As a result these systems also act as both “recorders” and “drivers” of natural and anthropogenic environmental change (Bianchi & Allison, 2009).

Knowledge of particle size distributions and composition in these highly complex systems is crucial for understanding many facets of ecosystem structure, variability and change, such as sediment fluxes, phytoplankton dynamics, that influence the underwater light climate and biogeochemical cycling in addition to geomorphological change. In particular, material in water that spills out onto floodplains can be deposited and have implications for sensitive riparian habitats. However, there is a lack of consistent data collected systematically and at sufficient spatial and temporal scales to allow greater understanding of the role particle size and composition play in the functioning of river-sea systems.

Recent developments in sensor technology (in-situ and space-borne) enable a more detailed characterisation of aquatic systems at high temporal frequency and large scales. For example, laser-diffraction based sensors now allow the in-situ determination of particle size and concentration in aquatic systems, while electron microscopy coupled with energy dispersive capabilities can adequately characterise submicron particle populations in the lab. Flow cytometry is able to rapidly characterise and quantify phytoplankton / bacterioplankton communities (Read et al 2014). In parallel, Earth observation (EO) satellite missions such as ESA Sentinel-2, -3 offer a great opportunity of basin-scale monitoring of water properties over the surface water continuum. In order to enable the use of the abovementioned technologies for characterising suspended particles in river-sea systems, methodologies need to be tested, refined and/or advanced.

The main aim of this PhD is twofold: 1) to understand sediment sources and their conveyance through river-sea systems; and 2) to establish functional relationships between optical properties and sediment characteristics in these systems.
This PhD will focus on two contrasting UK river-sea systems:

1) **Tay - North Sea**: The River Tay catchment covers an area greater than 5000 km$^2$ and is the largest river catchment in Scotland. The Tay catchment produces more freshwater input to the sea than the River Thames and Severn combined (Ferrier, 2008). A significant proportion of waterbodies (approximately 26%) in the Tay catchment are impacted by abstraction, diffuse source pollution, flow regulation, morphological alterations and point source pollutant pressures (SEPA, 2012b). The catchment population is concentrated in the south-east lowlands which is home to the cities of Perth and Dundee. Furthermore, the NERC LOCATE (Land Ocean Carbon Transfer) programme also focuses on the Tay catchment as a targeted study site. This is a 5 year research project in collaboration with the Centre for Ecology & Hydrology (CEH) that aims to quantify the fate of terrigeneous organic matter from land to the ocean, with particular focus on estuaries and coastal waters (www.locate.ac.uk).

2) **Thames – North Sea**: The second longest river in Britain and houses one fifth of the UK population. The catchment varies from relatively rural Chalk streams to urban-impacted rivers and the London Megacity around the estuary. It is regularly affected by drought and flooding, excessive nutrient enrichment from sewage and intensive agriculture, and algal blooms. The catchment has been intensely monitored since 2009 under CEH’s Thames Initiative research platform, and is also part of LOCATE.

This project builds on the world leading EO capability that was developed during the NERC GloboLakes project (2012-2018; www.globolakes.ac.uk) and the expertise that has been brought together through the H2020 projects Danubius-RI (2016-2019; http://danubius-pp.eu and http://www.danubius-ri.eu) and MONOCLE (2018-2022: Multiscale Observation Networks for Optical monitoring of Coastal waters, Lakes and Estuaries) and CoatsObs (2017-2020; Commercial service platform for user-relevant coastal water monitoring services based on Earth observation). This will provide important areas of further research collaboration.

**Methodology**

1) *In-situ characterisation of bio-geo-optical properties and sediment size distributions*: attenuation, absorption and scattering at 5 different size fractions (Wetlabs AC-9); spectral backscattering (Wetlabs ECOBB9); determination of particle size (LISST-100 and LISST-200X); Subsurface irradiance reflectance and above water-leaving reflectances (Satlantic HyperOCR and Trios RAMSES); Chlorophyll; coloured dissolved organic material, turbidity.

2) *Detailed particle characterisation in the laboratory*: This will include single particle size and chemical composition determined by a scanning electron microscope equipped with energy dispersive X-ray. Samples will be also analysed for concentration of organic/inorganic suspended material, particle size, phytoplankton cell abundances (Beckmann Flow Cytometer) and specific absorption coefficients.

3) *Earth observation*: Both ESA Sentinel 2 and 3 satellites along with archived Envisat data will be exploited to retrieve information on suspended sediments from these environments. Simulated (Hydrolight) spectra will also be generated to fill gaps in the in situ data record, to contribute to algorithm development and uncertainty characterisation.

**Images** - Top: Optics cage for the determination of in water bio-geo-optical properties; Middle: SEM image of suspended particles from Danube Delta and Bottom: Sentinel-2 image of River Tay.
Timeline

The PhD student will be mainly based at University of Stirling, with time spent at Centre for Ecology & Hydrology, Oxfordshire.

0-9 months: Development of the research proposal review and science plan, site visits and initial training in research design, laboratory sample analysis, data analytics and EO.

9 month progress review.


16-22 months: Data analytics; Samples analyses; Establish functional relationships between optical properties and sediment / algal characteristics in these systems.

24 month progress review.

23-28 months: EO data processing, sediment sources and their conveyance through river-sea systems

29-35 months. Final analysis

36-42. Write up and submission.

Training & Skills

The candidate will develop skills in a wide variety of state-of-the-art field and lab techniques used for characterising suspended particles (e.g. LISST, SEM/X-ray).

The candidate will also be trained in processing satellite image data and the application and tuning of algorithms for the accurate retrieval of in-water constituents, including atmospheric correction, and the development of processing chains. The candidate will be equipped with the know-how to perform accurate measurements of bio-optical properties and carry validation activities of remote sensing data and products for several available sensors. The measurements will include for example: spectral attenuation, absorption and scattering (Wetlabs AC-S; Wetlabs AC-9; Trios OSCAR); spectral backscattering (Wetlabs ECOBB3; HobiLabs Hydroscat; OBS); subsurface irradiance reflectance and above water-leaving reflectances (Satlantic HyperOCRs and HyperSAS; Trios Ramses). The applicant will be also trained in laboratory skills and analysis of bio-optical and radiometric data.

The candidate will present their findings annually within a postgraduate research symposium specific to Stirling, and international conferences. The student’s progress will be subject to annual progress reviews. All research students are members of Stirling’s Institute of Advanced Studies and are encouraged to attend seminars (that are particularly relevant to them in addition to the generic training skills provided by the IAPETUS DTP. Students also take advantage of the opportunities for networking with external visitors and students from other academic areas to promote interdisciplinarity.

References & Further Reading


Further Information

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