New RV Belgica

Specific call for research proposals 2021

'FULL PROPOSAL DESCRIPTION'

(Compulsory document – must be completed)

Before completing, please read carefully the ***Information document containing also the submission and evaluation guidelines and budget rules****.*

PROPOSAL's ID	
Proposal Acronym	TURBEAMS
Proposal Title	Towards 3D **TUR**bidity by correlating multi**BEAM** sonar and in-situ **S**ensor data

Please note that the font used to complete the documents must be Calibri, size 11, with 1.15 line spacing.

0. PROMOTOR/PARTNERSHIP

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1. PROPOSAL SUMMARY

Turbidity (or the cloudiness of water) is related to the concentration and type of suspended particles in the water column. These particles may be either of planktonic (both zoo- and phytoplankton) or sedimentological origin (resuspension of surface-bound sediments). Combined they form a cloud of **suspended particulate matter** (SPM) which affects light penetration in coastal waters. In order to ensure good water quality, turbidity and SPM have been monitored in the Belgian Part of the North Sea (BPNS) for decades, either in 1D (moorings, ship-based samples, tripodes on the seafloor, …) or in 2D (Acoustic Doppler Current Profiler, ADCP, transects). However, studies have indicated the very dynamic nature of SPM variability and the complex shape turbidity clouds can have. This justifies the need for **3D measurements** of turbidity and SPM.

A possible solution lies in multibeam sonars which, next to seafloor bathymetry data, are also able to deliver a 3D dataset of backscatter values in the water column. However, these 3D datasets are still scarcely used in quantitative turbidity and SPM assessments of the water column. One of the causes is that available software lacks proficient processing capabilities and it is not flexible enough to apply new innovative water column processing techniques. Another problem lies in the relationship between the acoustic return signal and the variable character of SPM, which is still insufficiently resolved. The latter problem is thereby not specific to multibeam systems, but to all acoustic echo sounder devices (e.g. ADCPs). The development of an innovative methodology and software that could tackle these problems and convert acoustic water column data to quantitative 3D turbidity and SPM information would be extremely relevant for both science and industry. Scientists would be able to derive SPM concentrations within the water column over large areas or investigate plumes generated by storm events. Industry would benefit from the advanced 3D investigation capabilities of the technique, which for example would allow for monitoring environmental impact of sediment plumes from bottom-disturbing activities, like sand dredging or bottom-trawling fishing activities.

The ultimate goal and most anticipated result of the TURBEAMS project will be the development of a methodology, which leads to **3D turbidity and SPM imaging based on multibeam water column data**, improving future monitoring tools. In order to reach this goal, we outline 4 research objectives. The **first objective** of the project is to determine **SPM characteristics** (type, size and concentration). The **second objective** is to **quantify the relation between multibeam water**

column data and SPM-related parameters (SPM type, concentration, grain size, optical turbidity) derived from in-situ optical and acoustic sensors. For this, we will use statistical and machine learning methods (e.g. Bayesian Evidential Learning) to analyse the large amounts of data from the many different sensors and additional environmental parameters (e.g. water currents). This novel approach allows for empirically revealing the most relevant parameters and for building a predictive model of the quantified relationships while assessing uncertainties. The **third objective** of the project is to **develop a** new water column multibeam **processing library** that allows for **flexible and efficient data processing and rapid visualization** using python scripts. Then we want to use this library to develop user-friendly workflows that can be applied by other scientists. Using the results from the previous objectives, the **final (and fourth) objective** of the project is to analyse the small-scale, seasonal and spatio-temporal variability and vertical distribution of SPM concentration with special attention on the near-bed SPM concentration in view of evaluating SPM concentration derived from multibeam echosounding for **monitoring human impacts**.

A fit-for-purpose acquisition strategy, together with specialized and newly-developed processing techniques will be implemented to fulfil the objectives, building on the survey approach adopted within the ongoing BELSPO-funded TIMBERS project (STEREO III call). The **acquisition strategy** consists of an absolute calibration of the acoustic backscatter values of the shallow-water multibeam, allowing exchange and comparison of data with other calibrated multibeam systems. We will deploy multiple acoustic systems of the RV Belgica (EM2040, ME70, EK80's and workhorse ADCP) and a wide range of readily available in-situ optical and acoustic sensors, in combination with the collection of water and plankton samples. Furthermore, we will implement a rigorous pinging strategy for the acoustic sensors, allowing simultaneous, yet non-interfering, acquisition of multi-frequency acoustic datasets. Moreover, all in-situ sensors will be tracked using the underwater navigation system of the RV Belgica (HiPAP). 3D multibeam water column data will be processed using a **data processing pipeline** that builds on the newly-developed processing library. The acoustic data will be converted into turbidity and SPM information based on the relation between multibeam backscatter values and in-situ sensor data.

The multibeam water column processing workflows and empirical relationships established during the TURBEAMS project may prove crucial in acquiring 3D turbidity and SPM information in marine environments and may serve as a **catalysator in follow-up research** proposals. Examples include monitoring turbidity changes at windmill farms or downslope turbidity flows in canyons systems, located on continental slopes.

Project duration: 4 years

2. COMPLIANCE WITH THE SCOPE OF THE CALL

Four main reasons illustrate how TURBEAMS fits within the call.

1. TURBEAMS is an innovative research project which will make full use of the **multi-frequency acoustic water column sensors** onboard the new RV Belgica. The EM2040 will be the main acoustic device of this project, but also the split-beam wideband echosounders (EK80's) will play a crucial role in obtaining calibrated backscatter values from within the water column at a

wide range of different frequencies. The Workhorse ADCP is pivotal as well as it yields 2D transects of SPM concentration. The synchronization unit will ensure the safe simultaneous recording by the different hydroacoustic sensors without interference. Additionally, relating multibeam and in-situ data requires precise localization of the sensor data. The available HiPAP system will provide this navigational accuracy and allow accurate comparison between all datasets.

2. The use of calibrated instruments is fundamental for the TURBEAMS project. As part of TURBEAMS, a backscatter check recorded by the equipment involved will be carried out regularly by different methods. Future RV Belgica projects can benefit from this **regular equipment check**. Furthermore, most of the acoustic sensors onboard will be put to test, which will result in useful feedback and best practices for future users of those sensors.
3. The current proposal builds on results obtained within an ongoing BELSPO-project: TIMBERS (STEREO III call). As such, **valorisation** of earlier, BELSPO-funded, results are ensured.
4. Finally, TURBEAMS will collaborate with the **Brain-project "BG-PART"** and exchange results with regards to the flocculation process within the water column. Flocculation has a huge effect on particle size and density, in turn altering the (acoustic) properties.

3. RESEARCH DESCRIPTION

3.1. OBJECTIVES AND STATE OF THE ART (MAX. 3 PAGES WITHOUT REFERENCES)

3.1.1. Research objectives and state of the art

State of the art: turbidity and SPM measurements in the North Sea

Suspended particulate matter (SPM) is an essential component in coastal waters, and comprises a wide variety of clay to sand-sized particles that are either biogenic (living zoo/phytoplankton and non-living organic matter) or sedimentological (physico-chemical and biogenic minerals, mainly resuspension of surface-bound sediments). Often, the organic biomass and sediments interact with each other and build large biomineral aggregates (flocs), controlling the fate and transport of SPM (Fettweis and Lee, 2017). **Turbidity** expresses the degree to which water loses its transparency, due to suspended particles that scatter or absorb light (Kirk, 1985; Gray and Gartner, 2009). Optical turbidity cannot be straightforwardly used as a proxy for SPM concentration due to two reasons. First, because absorption and scattering is also influenced by the physical characteristics of the suspended particles (Haalboom et al., 2021). Second, because turbidity is an arbitrary unit that strongly varies with applied protocols. This lack of comparability is why it is advisable to convert the sensor output into a mass concentration instead (Fettweis et al., 2019). Nevertheless, in TURBEAMS we would like to include **all facets of scattering** in the water column. Therefore, we will focus on a multiparameter characterization of both the cause (SPM concentration, types and sizes) of diminishing water clarity as the effect (turbidity). Optical turbidity is traditionally measured using a secchi disk, while water samples have been used to determine SPM concentration. In the past decades, more **in-situ non-intrusive methods** have emerged using acoustic or optical instruments (Rai and Kumar, 2015; Ouillon, 2018). In order to avoid confusion with the terminology in this proposal, the optical and acoustic sensor outputs will be further specified as optical and acoustic turbidity.

Monitoring **turbid areas in the Belgian Part of the North Sea** (BPNS) is important as it is one of the key parameters that can have a detrimental ecological impact (Capuzzo et al., 2018). Increasing human activities like the construction of offshore windmill parks (Baeye and Fettweis, 2015) and dredging activities (O'Connor, 1999), are known to have far-field effects and may significantly influence SPM variability. Improving our understanding of both natural and human-induced SPM variability is therefore essential for sustainable coastal management.

Large spatial datasets of optical turbidity and SPM patterns in the North Sea have been derived for years by **remote sensing** of ocean colour (e.g. Eleveld et al., 2008; El Serafy et al., 2011; Dogliotti et al., 2015; Fettweis et al.; 2021). However, these datasets are restricted to the **surface layer** of the water column. **Within the water column**, turbidity and SPM datasets are typically collected in-situ by a wide range of autonomous **optical and acoustic sensors** that are attached to stationary (e.g. tripodes) or moving platforms. In addition, gravimetric (and optical turbidity) measurements of filtered water samples are used as ground-truth reference. Despite the ability to monitor long-term and high-resolution time series, SPM and (optical and acoustic) turbidity in the water column are currently measured either in **1D stations** (e.g. Baeye et al., 2011; Baeye and Fettweis 2015; Fettweis et al., 2007; Fettweis and Lee, 2017) or in **2D transects** (e.g. Van Lancker and Baeye, 2015 Vanlede et al., 2019). Most coastal and near-shore areas, such as the BPNS, are dynamic environments where SPM patterns can exhibit large spatio-temporal fluctuations. Hence, there is a clear urgency to monitor these SPM changes with a **3D integrated, fast and cost-effective monitoring** approach.

A possible solution lies in **multibeam sonars**. These systems have originally been developed for collecting seafloor bathymetry, but thanks to advances in storage capacity and processing power, can nowadays also deliver a 3D dataset of backscatter values in the water column (Colbo et al., 2014). Only a handful of studies have used multibeam water column data to quantify suspended sediment in the water column. The studies were mostly conducted in a controlled environment (Simmons et al., 2017) or a semi-experimental set-up (Fromant et al., 2021). The ongoing TIMBERS project has demonstrated the potential of multibeam technology to map acoustic turbidity over a 3D volume in **uncontrolled environments**.

Objectives

Studies that focus on deriving quantitative turbidity and SPM information from multibeam data in natural environments are scarce, while these are necessary to better comprehend the dynamic and complex natural and anthropogenic hydro-sedimentary dynamics. In TURBEAMS, we aim to address this shortcoming by developing a workflow that allows **3D monitoring of turbidity and SPM using multibeam technology**, through the following objectives:

1. Determining SPM characteristics: Sensor response of optical and acoustical sensors may not only reflect changes in SPM mass concentrations, but also other SPM properties (such as shape, size, density, colour, refractive index, surface roughness, …) might affect scattering and absorption behavior (Pearson et al., 2021; Haalboom et al., 2021; Fettweis et al., 2019). **We hypothesize that biological and sedimentological dominated SPM assemblages can be discerned based on the interpretation of the sensor signal.** In order to verify this hypothesis, we first need to develop a

methodology to quantify the relative portions of biological versus sedimentological SPM in the water column. The relative portion of biological and sedimentological particles can be determined with niskin water sample analysis, but this method is labour-intensive and changes may have occurred between sampling and laboratory analysis. There are studies that derived the relative proportions of sand and mud in suspensions by comparing the response of simultaneous optical and acoustic measurements (Pearson et al., 2021). However, studies that focus on the in-situ distinction between biological and sedimentological scatterers are scarce. In this study we aim to tackle this issue by focusing on **inclusive in-situ imaging techniques** that are able to detect both SPM types.

2. Quantifying the relation between multibeam water column and turbidity or SPM data: Opposed to earlier studies, executed in (semi-) controlled environments (Simmons et al., 2017; Fromant et al., 2021), we opt to use an empirical approach in TURBEAMS. Specifically, we aim to collect multibeam water column and in-situ sensor data whilst the ship is moving, allowing us to compare co-located big datasets of multi-frequency acoustic turbidity and SPM-related parameters derived from the in-situ sensors. To analyse this complex dataset, we will use statistical and machine learning approaches, which will enable us to determine empirical relationships while assessing uncertainties. Since acoustic backscatter is not only a function of SPM concentration, but also the type and size of particles/aggregates, we intend to **interpret the acoustic signal in function of these SPM-related parameters and quantify their relative importance**. As the backscatter response to different particle sizes is dependent on the operating frequency (Wilson and Hay, 2015), we will **investigate if the use of multiple frequencies is key in discriminating particle sizes**. Finally, considering their different acoustic backscatter properties we will **explore if biological and sedimentological dominated SPM assemblages might produce a different signal**.

3. Developing Multibeam Water Column Processing Software: Current multibeam water column processing software lacks proficient processing capabilities. Commercially available packages mainly focus on visualization of pings or a limited amount of scatterers in the water column, while the few processing software packages that allow quantitative processing of multibeam water column data involve inflexible workflows. The increased use of water column data highlights the need for a powerful, yet user-friendly, open-access processing software. Hence, TURBEAMS aims to create **open-source libraries with processing functions** that can be directly accessed using a python interface.

4. Assessing spatio-temporal variability in Turbidity/SPM in the BPNS: The interaction between hydrodynamics and atmospheric forcing, as well as biological and chemical processes, affect concentration and composition of SPM on various spatial and temporal scales. The high resolution of multibeam-derived SPM concentration will allow quantifying small-scale variations related to turbulence, heterogeneity of seafloor composition and water depth. **We hypothesize that these 3D high-resolution SPM concentration datasets will shed new light on the near-bed SPM dynamics of which the understanding is critical in the monitoring of human-induced disturbances of SPM concentration and/or composition.** To this purpose, we will collect 3D datasets at different locations and along a transect from the offshore (low turbidity) towards the nearshore (high turbidity) during different seasons.

Why is the RV Belgica essential for TURBEAMS?

The RV Belgica harbours an impressive **tailored-for-TURBEAMS acoustic suite**, which is not present on any other research vessel in Belgium. Moreover, the **large rosette** enables the collection of 24 water (and SPM) samples, which can be precisely georeferenced "en route" with the underwater navigation **HiPAP system**.

Opportunities for new (inter)national collaborations

This project will be the first national transdisciplinary collaboration on multibeam water column data, which is a new, high-potential field of research. This was demonstrated by the presence of over 60 participants at a dedicated webinar in April 2021, coming from scientific, governmental and industrial sectors.

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3.1.2. Scientific risk of the project in relation to its objectives

The central paradigm In TURBEAMS is that we can deduce a relation between acoustic backscatter data and in-situ SPM and turbidity parameters. Based on the existing knowledge, the risk is negligible that this hypothesis is irrelevant. However, in TURBEAMS we will adopt an empirical strategy. In order to consider the constantly changing SPM characteristics in a natural environment, we will gather co-located big datasets of multi-frequency acoustic turbidity values and SPM-related parameters and investigate their empirical relationship and accompanying uncertainties. Furthermore, we aim to follow the best practice SPM monitoring workflow outlined in Fettweis et al. (2019). If the resulting uncertainties are too high to produce a meaningful empirical relationship, we will adjust or re-orient our approach. Nevertheless, we also plan stationary experiments for calibration purposes, which can act as a possible fall-back solution.

3.2. Translation of the research objectives into appropriate and well-described methodology (max. 10 pages)

3.2.1. Methodological approach

Strategy

To address the objectives of this project, we will take the following methodological steps. During seasonal campaigns with the RV Belgica, we will collect 3D/2D acoustic and 2D/1D in-situ (optical) turbidity and SPM datasets (**WP1**). In order to ensure comparability of the acoustic datasets over different campaigns, we will perform an absolute calibration of the shallow-water multibeam system onboard. After each campaign, the raw datasets of the individual sensors will be processed and converted into a georeferenced data format. Based on the in-situ sensors, we will determine (biological and sedimentological) SPM types, sizes and concentrations (**WP2**). Merging and comparing all obtained datasets will allow us to investigate empirically which in-situ parameters (e.g. SPM concentration, type, grain size, optical turbidity) correlate well with the various acoustic signals (**WP3**). The 3D multibeam water column datasets are typically quite large (several tens of GB), which hampers fast processing and straightforward correlation with in-situ sensor datasets. Therefore, we will use big data approaches (machine learning classifiers, Bayesian evidential learning - BEL) to determine the empirical relationships and assess the related uncertainty in a statistically sound manner (**WP3**). Throughout the project, we will develop open-source (Python) libraries (**WP4**), which will greatly increase the efficiency of the multibeam water column data processing. The obtained correlations (depending on tidal cycle, season, area, acquisition system) will finally be used to create and visualize 3D multibeam-derived turbidity and SPM information. These SPM concentration products will shed new light on small scale variability, while the seasonal sampling along transects will provide a better understanding of the SPM concentration along a transect from the high turbid nearshore towards the low turbid offshore (**WP5**).

Toolbox

Acoustics (backscatter and attenuation of acoustic signals in water) is one of those continuous measuring techniques that has been developed to characterize suspended sediments (e.g. Urick, 1948; Hay, 1983; Hay and Sheng, 1992; Gartner, 2004; Simmons et al., 2010, 2017; Best et al., 2010; Guerrero et al., 2011; Thorne and Hay, 2012; Pedocchi and Garcia, 2012; Fromant et al., 2021). In the TURBEAMS project, the main emphasis will be on acoustic monitoring (Figure 1). Therefore, we will be using a selection of **acoustic devices**, installed on the new RV Belgica, operating at **multiple frequencies**. These devices include the shallow-water multibeam (200-400 khz, EM2040; Kongsberg), the scientific multibeam (70-120 kHz, Simrad ME70; Kongsberg), the six split-beam wideband single beam echosounders (18-333 kHz, EK80; Kongsberg) and one of the ADCP's (600 kHz, Workhorse; Teledyne). In addition, an Acoustic Backscatter Sensor (ABS) will be used during the project, but is not permanently installed on the RV Belgica. Instead this ABS (300kHz-5 MHz; Aquascat1000R; Aquatec Group) will be mounted on the optical sensor frame (VPR, see below). All acoustic sensors in TURBEAMS are based on the principle of acoustic backscatter and deliver intensity values (in decibels).

The TURBEAMS toolbox also contains a variety of **optical in-situ sensors** (Figure 1), which are available at VLIZ as part of the research infrastructure disposable to the research community. We will collect real-time plankton images with the Video Plankton Recorder (VPR; Seascan Inc.). On the VPR, an Optical Backscatter Sensor (OBS, Eco FLNTU; Wet labs) and a Laser In-situ Scattering and Transmissometer (LISST-200X; Sequoia Scientific) will be mounted. All of these sensors measure turbidity/SPM in a slightly different and complementary way. The LISST measures the total volume concentration (in µl/l or ppm) and particle size distributions in 36 grain-size classes using the principle of laser diffraction (forward scattering). The VPR captures images (25 frames per second) using dark-field illumination while being towed underwater. The particle size range captured with the VPR (100 µm-few cm) complements the LISST range (1-500 µm). The OBS device, attached to the VPR, measures optical turbidity and chlorophyll at 700 nm wavelength using the principle of optical backscattered light at 140 degrees. This instrument is more sensitive to fine-grained material (Haalboom et al., 2021).

Ground-truthing of these continuous acoustic and optical sensor measurements will be done by **traditional sampling** methods (Figure 1). Vertical plankton nets (WP2) will be used to determine the vertical/diagonal abundance and distribution of mesozooplankton (~0.2-20 mm). We will also retrieve water samples from various depths with the Niskin carousel of the ship. These water samples will allow us to measure optical turbidity (in FNU, ISO 7027 protocol) onboard with a portable turbidimeter (2100QIS; Hach), using the ratio of the primary nephelometric light scatter signal (90°) to the transmitted light scatter signal. In the lab, the water and plankton samples will be further analysed with a variety of techniques to determine SPM concentration, size and composition (using filtration and gravimetric measurements) and plankton abundances (using Flowcam and Zooscan instruments).

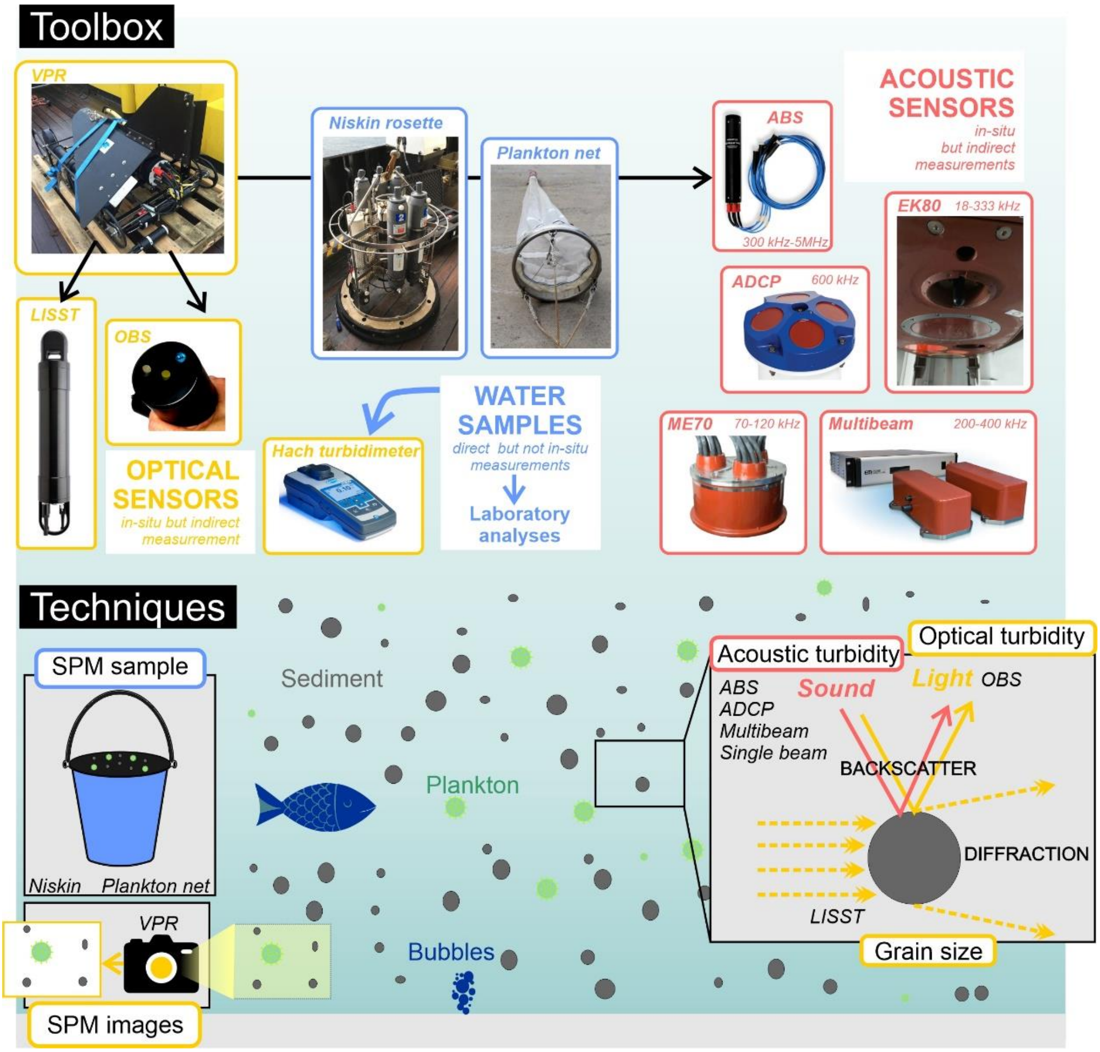

Figure 1: ***Top*** *– The TURBEAMS toolbox comprises optical (LISST-200X, Eco FLNTU OBS, VPR, Hach turbidimeter) and acoustic sensors (Aquascat ABS, Workhorse ADCP, EK80 single beams, ME70 multibeam, EM2040 multibeam), which are ground-truthed with Niskin water and plankton samples. Figure sources: see hyperlinks, EK80 (from RV Belgica_Survey Report 2006102 Revision 2).* ***Bottom*** *– Overview of a selection of techniques used in TURBEAMS. Acoustic sensors are based on the principle of acoustic backscatter. Regarding the optical sensors, the OBS measures backscattered light, the LISST measures the particle size distributions using the principle of laser diffraction (forward scattering). The VPR captures images using dark-field illumination.*

Innovative aspect

The strength of the TURBEAMS proposal lies in the original methodological approach, the cutting-edge technology onboard RV Belgica and the development of new water column multibeam processing tools.

First of all, **multibeam water column technology** as a monitoring tool is a new and emerging field within marine sciences. Consequently, the general aim and methodology put forward in this proposal is already extremely innovative. Only a handful of studies have investigated water column multibeam data for SPM quantification purposes, always conducted in a stationary (semi-) experimental set-up (Simmons et al., 2017; Fromant et al., 2021). In contrast to these studies (that estimate suspended sediment concentration through acoustic inversion methods and related backscatter formulas), we will build on the empirical approach developed in the TIMBERS project. Big 3D datasets of water column multibeam and in-situ sensor data will be collected "en route" in the **natural environment** of the BPNS, followed by a statistical multi-parameter characterization of turbidity and SPM. Our interdisciplinary approach will make use of state-of-the-art **big data statistical methods** (including Bayesian Evidential Learning), which have so far not been applied this way in the field of acoustic turbidity and SPM measurements.

Secondly, onboard the new RV Belgica, we will deploy an **impressive suite of acoustic and optical in-situ sensors** combined with traditional sampling techniques. We will maximally exploit the recording of the (multi-) frequency acoustic devices, using the K-sync system that synchronizes pinging of all devices into a real acoustic concert. This **multi-frequency**, **multi-sensor approach** will be necessary for tackling the issue of target ambiguity when interpreting multibeam data. For the first time, we will unlock the potential of multibeam data to discriminate between biological and sedimentological scatterers in the water column and their wide spectrum of sizes.

Finally, we would like to highlight that the much-needed development of a **software** that can handle large quantities of multibeam water column data is extremely challenging. If we succeed in developing the necessary open source (c++/Python) libraries within this project, this will be a tremendous advancement in this field allowing scientists to apply and improve new innovative processing techniques. Both science and industry will benefit from this, as the possibility to rapidly process and visualize multibeam-derived turbidity and/or SPM in 3D can be considered ground breaking.

3.2.2. Methodology

WP1: Data acquisition and processing (addresses objective 1-4)

Field work will be carried out on the RV Belgica during the **first three years** of the project. Both TURBEAMS-specific campaigns and joint campaigns with the BGCMonit program (Biogeochemical Monitoring on the Belgian Continental Shelf, funded by RBINS) will be conducted. In BGCMonit, monthly ship-based campaigns are carried out in three stations (MOW1-W05-W08) (Figure 2).

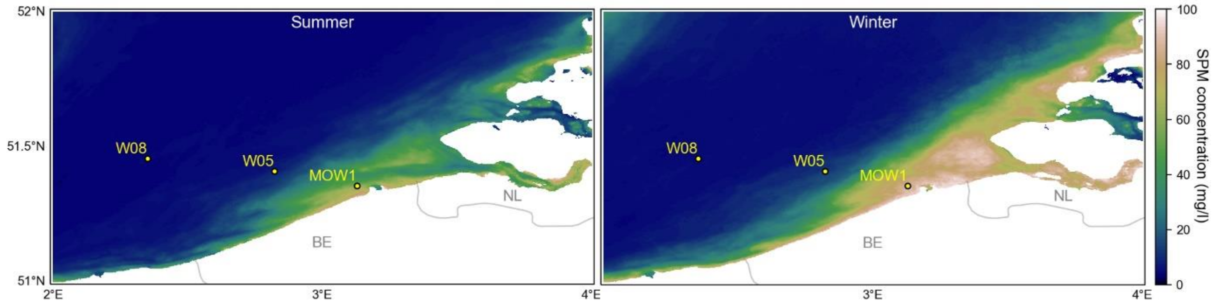

*Figure 2: Map of sampling stations MOW1, W05 and W08 on the Belgian continental shelf. The background displays the averaged near surface SPM concentrations computed from satellite images taken by Sentinel-3/OLCI from April 2019 to September 2019 (**left**) and from November 2019 to March 2020 (**right**).*

The characteristics of SPM (size, concentration) and composition (Organic matter parameters: TEP, POC, PON, DOC, DIC, pigments) are determined from water samples and from sensors (OBS, ADCP, LISST) during a tidal cycle. In other RBINS programmes, the spatio-temporal variability of SPM concentrations and sediment plumes are studied in sandbank areas subdued to aggregate and/or wind energy extraction. Piggybacking on a few of these campaigns, TURBEAMS will provide additional acoustic data for these programs, while simultaneously acquiring data for the project.
During the TURBEAMS-specific campaigns, transects will be sailed between MOW1-W05-W08 to collect all the necessary datasets (Task 1.2-1.4). The sampling strategy during the specific campaigns will consist of a yoyo-movement of the in-situ turbidity sensor frame (towed behind ship) and the Niskin rosette (towed at the side of the ship) with simultaneous multibeam water column data collection (Figure 3). Yoyo descent and ascent rates are as slow as possible, ranging around 20 cm/s. Meanwhile the ship must sail at low constant speed of about 3 knots, because drifting and turning of the ship may cause unwanted bubble wakes. All acoustic and in-situ turbidity and SPM data will be collected and processed into a predefined georeferenced format (Tasks 1.2-1.4).

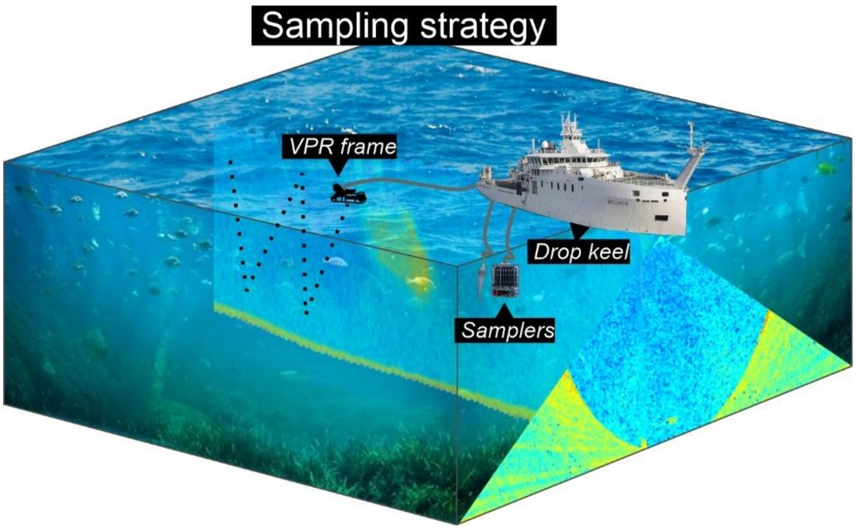

Figure 3 : TURBEAMS sampling strategy: yoyo-movement of the in-situ turbidity sensor frame (VPR, towed behind ship) and the samplers (rosette and plankton nets, towed at the side of the ship) with simultaneous recording of backscatter from acoustic sensors, installed on drop keels below the ship. Figure sources: see hyperlinks, [Water cube](), [Niskin rosette](), [plankton net](); [RV Belgica]().

Multibeam data is highly dependent on system-specific emission and reception beam patterns (Foote et al., 2005). Hence, corrections are necessary to harmonize the echo levels of the EM2040 and to ensure absolute values of the Volume Backscattering Strength (Sv) over its entire fan (for different frequency modes). The latter is important to let the sonar measure true referenced physical backscatter values (Lamarche and Lurton, 2018). In order to use the multibeam as a SPM monitoring tool in TURBEAMS, each beam will thus need to be calibrated (Task 1.1), which in fact requires significant (financial, material, human) resources (Simmons et al., 2017; Foote et al., 2005).

Task 1.1: Calibration Multibeam

Within the first six months of the project, Continental Shelf Service of FPS Economy (COPCO) and VLIZ will handle the calibration of the EM2040 backscatter (creation of BS correction files) for a series of usual and TURBEAMS-specific operating modes, using the EK80 (Eleftherakis et al., 2018; Fezzani et al., 2021). Subsequently, by a regular series of measurements on the Kwinte zone, COPCO will ensure the repeatability of the EM2040 data (Deleu & Roche, 2020; Roche et al., 2018).

⇒ *Deliverable D1.1.1***:** Calibrated beams for EM2040, BScorr file(s)

Task 1.2: 3D acoustic data

During each campaign executed during **the first three years**, VLIZ, UGent and COPCO will collect 3D multibeam water column data with the shallow-water **multibeam EM2040** onboard RV Belgica, using three frequency modes (200, 300, 400 khz) at the same time. This multi-frequency recording will be made possible after implementation of the newest SIS 5 update by Kongsberg. We will be using an updated version of the TIMBERS acquisition protocol. The multibeam will be deployed in single sector mode, using no filters to ensure high signal-to-noise-ratio. Acoustic interferences are avoided by using ping synchronization (Kongsberg K-Sync). The acoustic surveys will be designed to minimize distortion due to bubbles by refraining from using dynamic positioning during the campaigns. Moreover, the potential of the scientific multibeam (ME70) will be assessed in the beginning of the project, potentially adding it as a tool for the remainder of the project.
Processing large quantities of raw multibeam water column data needs specialized processing workflows and software. At first, we will do basic processing using Sonarscope (IFREMER) as has been done in the TIMBERS project. But gradually we will adapt advanced and more automated workflows made possible by the developed multibeam water column libraries (see WP4).

⇒ *Deliverable D1.2.1***:** Seasonal datasets of georeferenced 3D acoustic data

Task 1.3: 2D acoustic data

During each campaign executed during **the first three years**, 2D acoustic data will be collected along transects using an ADCP (RBINS) and six EK80's (COPCO, UGent), installed on the drop keels below the ship. Regular calibration of the EK80's is foreseen using reference spheres, available onboard. For processing of the **EK80** data, we will use ESP3, which is an open-source software tool that provides the necessary routines to filter the data, process calibration results and export volume backscattering values. To simplify the overall workflow of the project, it could be beneficial to implement basic processing capabilities of EK80 data within the created water column software (WP4). However, this is an optional goal on which we will decide during the project. Regarding the **ADCP** data, the on-board RDI(c) VmDas acquisition system will monitor the hydrodynamics and depth. General processing scripts from the OCE (Oceanographic Analysis) R library will be used, together with existing scripts from RBINS for acoustic inversion.

⇒ *Deliverable D1.3.1:* Seasonal datasets of georeferenced 2D acoustic data

Task 1.4: 1D/2D in-situ turbidity and SPM data

During each campaign executed during **the first three years**, RBINS and VLIZ will collect stationary (1D) or (yo-yo) transects (2D) in-situ (optical) turbidity and SPM data. Both VLIZ and RBINS will focus on the **optical sensors** (VPR, OBS, LISST, Hach), while RBINS will be responsible for processing the **acoustic in-situ sensors** (ABS) and the laboratory analyses of the **water samples**.

⇒ *Deliverable D1.4.1***:** Seasonal dataset of georeferenced 1D/2D in-situ turbidity and SPM parameters

WP2: Determine SPM characteristics (addresses objective 1)

After processing of the data of the first campaign, TURBEAMS will use the multi-frequency acoustic (D1.2.1-D1.3.1) and the in-situ sensor datasets (D1.4.1) in order to determine SPM types and sizes (Task 2.1) and SPM concentrations (Task 2.2).

Task 2.1 Determine SPM types and sizes

The relative portion of biological and sedimentological particles can be determined with Niskin sample analysis, but this method is labour-intensive and changes may have occurred between sampling and laboratory analysis. Therefore, VLIZ will develop **from the start of the project** (first using legacy data and later with newly acquired data) a method to determine SPM types and sizes using continuous measurement techniques.
The size distribution of SPM will be determined using the LISST-200X (size range between 1 and 500 µm). In order to investigate the relative proportion of sedimentological and biological particles within SPM assemblages, two novel yet challenging approaches will be put to test. The VPR is mainly used as a non-intrusive underwater microscope that records images of plankton (from 100 µm up to a few centimetres in size). However, this camera also captures minerogenic material and flocs. Instead of ignoring this sedimentological fraction, we will investigate if automated image analysis will allow us to derive specific SPM characteristics (i.e. plankton and mineral percentages, grain size of particles) based on processing techniques used in CT data analysis (Vandorpe et al., 2019). We will verify these findings by analysing Niskin water samples using the Flowcam (2µm-2mm) and Zooscan (> 200 µm), available at the VLIZ laboratories. Additionally, the high sampling frequency (1 MHz) of the EK80 makes it possible to sample the full wavelet of the reflected acoustic signal, theoretically allowing the calculation of the size and origin of the particles, based on analysis of reversal and absorption characteristics. We will evaluate if this seismic signal processing approach might be an interesting tool for SPM characterization.

⇒ *Deliverable D2.1.1:* Detection method SPM types and sizes
⇒ *Deliverable D2.1.2*: Seasonal georeferenced dataset of SPM types and sizes

Task 2.2: Determine SPM concentration

To allow comparisons between SPM measurements, it is recommended to transform the sensor output into mass concentration (in g/l). So, after each campaign (**first three years**), VLIZ and RBINS will use the Niskin SPM concentration (obtained from filtration and gravimetric measurements, $SPMC_{Niskin}$) (D1.4.1) to ground-truth and convert the collected 2D acoustic (D1.3.1) and optical (D1.4.1) sensor output to a surrogate $SPMC_{Sensor}$. Furthermore, in the first year we will investigate if it is justified to use Hach optical turbidity (in FNU) as a surrogate for $SPMC_{Niskin}$, as outlined in

Fettweis et al. (2019). This would significantly minimize the laboratory effort in the following two years, whilst yielding more calibration data.

⇒ *Deliverable D2.2.1*: Seasonal dataset of georeferenced SPM concentrations

WP3: Quantifying the relation between multibeam water column and turbidity or SPM data (addresses objective 2)

All obtained datasets will be compiled into the TURBEAMS data table (Task 3.1). After geospatially merging all measurements (D1.2.1-D1.4.1) and calculated parameters (D2.1.1-D2.2.1), the relationship between multibeam water column and turbidity/SPM data will be further investigated (Task 3.2).

Task 3.1: Compile all datasets

Starting after the first campaign, all partners will **continuously** update the TURBEAMS data table with georeferenced 3D acoustic (D1.2.1), 2D acoustic (D1.3.1), 1D/2D in-situ turbidity and SPM data (D1.4.1), as well as georeferenced SPM characteristics (D2.1.2-D2.2.1).

⇒ *Deliverable D3.1.1:* Compilation dataset

Task 3.2: Establish the optimal relationships

The compiled database (D3.1.1) will contain co-located multi-frequency acoustic and in-situ (optical) turbidity and SPM data, which allows UGent to investigate their empirical relationship using statistical and machine learning approaches. This task can only start after the first campaign, but will go on **continuously** until the final six months of the project. A strategy will be proposed to forecast turbidity or SPM parameters (target) based on the acoustic data (predictor). We will investigate three broad strategies. In the first strategy, we will study the prediction of turbidity and SPM using **data-driven predictive modelling techniques** (e.g. random forest regression or convolutional neural networks). Spatial autocorrelation can be incorporated by augmenting the input data with spatial contextual features (such as location and observations of nearby samples). Alternatively, models can be studied that incorporate spatial dependency in the model structure (e.g. Gaussian process-based models) or add spatial regularization in the objective function for learning (e.g. a graph Laplacian regularizer). In the latter, the learning algorithm favours parameter values that not only make accurate predictions at individual locations but also show high spatial autocorrelation in predictions. In a second strategy, the target will be categorized in classes so that the problem becomes a **classification problem**. This is meaningful as (1) decisions are often based on thresholds, (2) the geophysical predictor has limited resolution which limits its ability for prediction and (3) working with categories makes the analysis of uncertainty more straightforward. Many different approaches exist to solve such a problem (e.g., Scheidt et al., 2018), but we prioritize two data-driven methodologies. The first one is a probabilistic approach based on building conditional probability distributions (Hermans and Irving, 2017). This can be directly obtained from the co-located data set. The second approach uses a classification machine learning algorithm based on a neural network called multi-layer perceptron (MLP). (Goodfellow et al., 2016). Both approaches provide the probability to belong to each category and thus to estimate uncertainty. They allow the integration of any number of input variables (Journel, 2002), including spatial neighbours (Caers and Ma, 2002) and spatial trends. In the third strategy, we will consider continuous targets and adapt **Bayesian**

Evidential Learning, a prediction-focused approach, (BEL, Hermans et al., 2018) for the prediction. In contrast to neural network-based algorithms, BEL forecasts the full posterior distribution of the targets and thus allows assessing uncertainty. This is possible because the learning phase approximates the complex multi-dimensional joint probability distributions in a reduced dimension space where several bivariate relationships are linearized, allowing straightforward prediction (Scheidt et al., 2018). BEL has been developed for prediction problems involving multiple correlated target and predictor variables and is thus particularly well suited to solve problems involving spatially distributed data. In this project, it will thus allow to jointly predict several targets (turbidity, concentration and grain size for each SPM type), and identify which ones can be deduced from acoustic data. All models considered can be trained and validated in a cross-validation process. Selection between different modelling techniques will be based on a trade-off between performance and model complexity (e.g. by using criterions as Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC)).

⇒ *Deliverable D3.2.1:* (optimized) relationships

WP4: Developing MULTIBEAM water column processing software (addresses objective 3)

The water column processing software is seen as a c++/Python library, which provides all necessary functions for reading, georeferencing, gridding and exporting multibeam water column data (Task 4.1). These (Python) functions are then used to create data processing pipelines to convert the raw multibeam water column data to 3D volume backscattering grids that will be used by the other work packages (Task 4.2). Ultimately, the multibeam data will be converted to 3D turbidity and SPM estimates using the results from WP3 (Task 4.3).

Task 4.1: Develop a multibeam water column processing library

To allow for a high processing speed and efficiency of the routines, the library will be created in c++. The actual data processing however will be done in Python. For this, the functionality of the library will be exposed to Python using the library “pybind11”. For the development of such a hybrid library that gives access to the benefits of both Python and C++, we have access to expertise and (so far) unpublished software code supplied by GEOMAR.

The necessary core functionality of the planned library can be split in three components:

1. **Multibeam Input:** This component provides the ability to read multibeam datafiles, provide access to the raw data and the ability to extract necessary variables (e.g. calibrated volume backscattering values, navigation data and motion data) as structures that can be efficiently used by the other two components of this library.
2. **Multibeam sample georeferencing:** This component includes the ability to interpolate and transform navigation and motion data and to compute the correct georeferenced position of the individual multibeam samples in the water column using ray-tracing routines.
3. **Scatter point processing and data exporting:** This component provides functions that allow to reduce the size of the (filtered) 3D scattered data, grid them and export them into data formats and tables accessible by other programs.

To increase the accessibility of the created processing library for scientists, we will provide jupyter notebooks with tutorial workflows that show how basic processing and data visualisation can be achieved using this library (WP8, Task 8.2).

⇒ *Deliverable D4.1.1:* Finished core functionality (allowing to load, georeference, grid and export multibeam data).

Task 4.2: Create data processing pipelines for the work packages

Using the newly-developed core functionality, we set up processing pipelines as jupyter notebooks for the available input data.

⇒ *Deliverable D4.2.1:* Multibeam processing pipelines for the work packages of this project

Task 4.3: Turbidity module: Integrate turbidity and SPM estimation equations

The relations between acoustics and turbidity/SPM established in WP3 will be implemented into a conversion tool in the software, rendering 3D estimates.

⇒ *Deliverable D4.3.1:* 3D turbidity/SPM estimates (using the results from WP3)

Within the **first year**, UGent will concentrate on Task 4.1. A first beta release of the processing library is planned within the second year. In the **second year**, UGent will focus on implementing the data processing pipelines to provide the necessary processed data output for the other work packages (Task 4.2). In the **third and fourth year**, UGent and VLIZ will simplify the pipelines such that they can be applied by other scientists and implement the turbidity and SPM estimates (Task 4.3) using the methods developed in WP3.

WP5: Scientific analysis of acoustic and optical backscatter data on the BPNS (addresses objective 4)

In this WP, the in-situ measurements of SPM concentration derived from multibeam (D4.3.1) and ADCP backscatter (D2.2.1) will be used to analyse the spatio-temporal variability and vertical distribution of SPM concentration and composition (Tasks 5.1-5.3).

Task 5.1: Small-scale variability of SPM concentration

The relationship between SPM concentration/composition and the acoustic backscatter appears highly variable for ADCP backscatter. This is caused by (1) the complex nature of particle scattering whose details are difficult to reveal, (2) the natural variability of SPM concentration due to turbulence, (3) the spatial mismatch between water sampling and the ADCP bin and (4) the uncertainty of the measurements. Multibeam water column data can provide high resolution over a swath width. This will allow RBINS to assess SPM variability in a 3D volume of water. This task will start after the first campaign (**year 1**) and continue until the end of the project (**year 4**).

⇒ *Deliverable D5.1.1:* Natural variability of SPM concentration in the coastal turbidity maximum and the low turbid offshore zone using high resolution multibeam data.
⇒ *Deliverable D5.1.2:* Relation between the variability of lower resolution sensors (ADCP, OBS, water sample) and multibeam water column data

Task 5.2: Seasonal variation in SPM characteristics along a nearshore to offshore transect

The SPM concentration is high in the nearshore area and decreases towards the offshore. This goes together with a change in composition and floc size as well as bathymetry and turbulence. Nearshore SPM is dominated by mineral particles and smaller floc sizes, while offshore SPM is dominated by organic particles with larger sizes. Contrary to the nearshore area, the offshore area is deeper and less dynamic. The transition is clearly visible in satellite images at the surface, but how the transition occurs throughout the water column and how the turbidity maximum extends offshore near the bed is not clear. Therefore, RBINS will investigate the seasonal change in SPM characteristics using ADCP and multibeam data. Regarding the ADCP data, the task can start after the first campaign in the **first year**, while the MB-derived SPM concentrations (D3.2.1) will be available from the **third year** onwards.

⇒ *Deliverable D5.2.1:* Seasonal change in concentration and composition of SPM based on the ADCP and multibeam transects (MOW1-W05-W08)

Task 5.3: SPM concentration in the benthic layer

SPM flocs have a density that is larger than the density of seawater, meaning that their concentration increases (generally) towards the seafloor. Contrary to other sensors or water sampling, high-resolution multibeam allows to measure the benthic boundary layer in detail and to construct a complete SPM concentration profile. A detailed vertical profile will allow RBINS to estimate the SPM matter involved in deposition and resuspension more accurately. Moreover, it will allow for estimating the effect of SPM matter on turbulence damping, which occurs when SPM concentrations are higher than 10 g/l. Such values are known to occur in the turbid nearshore areas. New insights are expected on near-bed SPM dynamics which is highly relevant for the monitoring of human impacts (e.g., dredging and dumping, sand mining, offshore wind farms). This task is scheduled for the **third and fourth year**.

⇒ *Deliverable D5.3.1:* SPM profiles and quantification of near-bed SPM dynamics
⇒ *Deliverable D5.3.2:* Added value of multibeam-derived SPM dynamics in assessing human-induced changes in SPM concentration.

3.2.3. Gender

Not relevant/applicable

3.2.4. Ethic aspects

	Humans	YES	NO
*	Does the proposed research involve humans (children, patients, volunteers, vulnerable people)?	☐	☒
	Human Embryo/Foetus	**YES**	**NO**
*	Does the proposed research involve human embryos?	☐	☒
*	Does the proposed research involve human foetal tissues/cells?	☐	☒
*	Does the proposed research involve human embryonic stem cells?	☐	☒

	Human Cells and/or Tissues	YES	NO
	Does your research involve the use of human cells or tissues (other than from human embryos and/or foetuses)?	☐	☒
	Privacy	**YES**	**NO**
	Does the proposed research involve collection and/or processing of genetic information or personal data (e.g. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	☐	☒
	Does the proposed research involve tracking the location or observation of people?	☐	☒
	Animals	**YES**	**NO**
	Does the proposed research involve research on animals?	☐	☒
*	Are those animals non-human primates?	☐	☒
	Environment, Health and Safety	**YES**	**NO**
	Does your research involve any activities or the use of elements that may cause harm to the environment, animals, or plants (e.g., GMO plants, microorganisms, etc.)?	☐	☒
	Does your research involve the use of elements (toxic chemicals, explosives, radioactive material, etc.) that may cause harm to humans, including the research staff?	☐	☒
	Other Ethical Issues	**YES**	**NO**
	Are there any other foreseen activities that may raise ethical issues or that should be taken in consideration?	☐	☒
	If yes please specify: Click here to enter text.		

4. IMPLEMENTATION

4.1. Network expertise (only for network project)

4.1.1. Individual quality of the partners (max. 3 pages/partner)

Flanders Marine Institute (VLIZ)

Flanders Marine Institute (VLIZ) is an autonomous scientific institute that provides various services to the Belgian marine scientific community and actively seeks to initiate, support or conduct interdisciplinary marine research. Our core-activities range from data archiving and educational activities for the public to delivering policy-informing briefs and providing technical support for marine research. Since its creation, VLIZ has gathered over 20 years of experience with a wide array of scientific infrastructures. Examples include the VPR (video-based plankton observation), the LISST200-X (grain-size measurements in the water column based on laser diffraction) and several acoustic systems, among which two multibeam systems (the hull-mounted EM2040 and the portable Norbit WBMS) and an acoustic positioning system (GAPS). The experience is demonstrated through our long-term engagements in European Research Infrastructures (ESFRIs) such as the Integrated Carbon Observation System (ICOS) and the LifeWatch-ERIC observatory, but also

through our collaboration in a large amount of scientific research projects, including TIMBERS, a project where an onset towards 3D turbidity monitoring is attempted.
Coordinator for VLIZ will be Dr. Thomas Vandorpe (infrastructure division), supported by Dr. Nore Praet (research division). Nore and Thomas have already proven their ability to work closely together as a team, as they are collaborating on the TIMBERS project.

Coordinator: Prof. Dr. Vandorpe

Dr. Thomas Vandorpe (9 January 1987) is a senior technician/geophysicist at VLIZ who completed his PhD in 2017 at Ghent University. During his PhD, he used multibeam bathymetric, subsurface seismic, (lowered) ADCP and sediment core data to reconstruct the palaeoceanographic history of the southern Gulf of Cadiz. As such, Thomas gained invaluable experience with acoustic systems, a skill he further developed during his employment at VLIZ. There, Thomas is responsible for many of the acoustic detection systems, most importantly the EM2040 and Norbit WBMS multibeam systems. Thomas is also in charge of the underwater navigation equipment GAPS, which is very similar to the HiPAP system onboard the new RV Belgica. Besides the management of the acoustic systems, Thomas also coordinates two projects: the BELSPO-funded TIMBERS project and the Blue Accelerator project. In his scientific career, Thomas published 15 peer-reviewed articles (h-index 9) and contributed to numerous conferences and workshops. Together with Nore Praet, Marc Roche (FOD Economy) and Jean-Marie Augustin (IFREMER), Thomas co-hosted the webinar on multibeam water column data, on the 19th of April 2021. Moreover, Thomas is a guest-lecturer at Ghent University, teaching the multibeam part of the course "Integrated Offshore Exploration", focusing on the acquisition, processing and visualization of multibeam data (elective course in "Master of Science in Geology'' and "Master of Science in Marine and Lacustrine Science and Management").

ORCID: https://orcid.org/0000-0002-1461-2484

Collaborator: Dr. Praet

Dr. Nore Praet (12 August 1990) is a researcher at VLIZ, working on the TIMBERS project. Nore received her PhD degree in 2020 from Ghent University. During her PhD, Nore reconstructed the seismological history of Alaska through the study of lake sediments using a combination of multibeam bathymetric, subsurface seismic and sediment core data. Nore has published a total of 10 publications in peer-reviewed journals and one book chapter (h-index 7). Also, she attended numerous conferences and was an invited speaker at the SSA annual meeting (2017) in Denver. After her PhD, she specialized in measuring (3D) turbidity in Belgian coastal waters, mainly in the framework of the TIMBERS project. During the past years, she gained invaluable experience in acquiring and processing multibeam water column data and in-situ sensor data. This is evidenced by co-hosting the webinar on multibeam water column data on April 19th 2021. Furthermore, during her PhD and TIMBERS, she got acquainted with conducting statistical analyses on big multivariate datasets.

ORCID: https://orcid.org/0000-0002-5567-3718

Collaborator: Dr. De Rijcke

Dr. Maarten De Rijcke (2 March 1988) is an early career, senior researcher at VLIZ that obtained his master degrees in Marine Biodiversity and Conservation (2012) and Environmental Management

(2013), followed by his PhD (2017) from Ghent University. He has published 18 A1 publications (h-index 10). During his PhD, he worked on the current and future risks of harmful algal blooms in the North Sea by combining toxic effects assessments for shellfish cultivation and competition experiments with toxic and non-toxic algae. Through this research, he gained first-hand experience with experimental setups for both phytoplankton and zooplankton, analytical chemistry and trait-based modelling. He started working as the Infrastructure Science Manager in the new research department of VLIZ in 2017. In the first two years, he was responsible for the design and procurement of new facilities (labs, climate rooms, equipment), initiated and passed on a new research line on microplastics, and secured over 1M€ external funding through interdisciplinary project writing. Since 2019, he now leads a small research unit (3 PhD students, 1 postdoc) dedicated to topics within the field of microbial ecology (e.g. aerosolization of marine biogenics and bacteria; role of viruses in the Belgian North Sea).

ORCID: https://orcid.org/0000-0002-0899-8122

Relevant projects

- 3D Turbidity assessment through integration of Multibeam Echo-sounding and optical Remote Sensing (TIMBERS) – BELSPO stereo call 2018, duration: 30 months (+6 months extension)
- BioGeochemical PARTicle interactions and feedback loops on the Belgian continental shelf – BG-PART – BELSPO Brain-be 2.0 project call 2020-2021, duration: 48 months

5 most relevant publications

- **Vandorpe, T.**, Martins, I., Vitorino, J., Hebbeln, D., García, M., Van rooij, D., 2016. Bottom currents and their influence on the sedimentation pattern in the El Arraiche mud volcano province, southern Gulf of Cadiz. Marine Geology 378, 114-126.DOI: 10.1016/j.margeo.2015.11.012
- **Vandorpe, T.**, Collart, T., Cnudde, V., Lebreiro, S., Hernández-Molina, F.J., Alonso, B., Mena, A., Antón, L., Van Rooij, D., 2019. Quantitative characterisation of contourite deposits using medical CT. Marine Geology 417, 106003. DOI: 10.1016/j.margeo.2019.106003
- García-Moreno, D., **Vandorpe, T.**, De Clercq, M., Roche, M., Vertino, A., Missiaen, T., 2021. Characterisation of Middle–Late Pleistocene groove-and-ridge landforms incised across the Dover Strait. Geomorphology, 376, 107517. DOI: 10.1016/j.geomorph.2020.107517.
- **Praet, N.**, Van Daele, M., Collart, T., Moernaut, J., Vandekerkhove, E., Kempf, P., Haeussler, P.J. & De Batist, M., 2020. Turbidite stratigraphy in proglacial lakes: Deciphering turbidite trigger mechanisms using a statistical approach. Sedimentology 67, 2332-2359. DOI: 10.1111/sed.12703
- Bolton, M., Jensen, B., Wallace, K., **Praet, N.**, Fortin, D., Kaufman, D. & De Batist, M., 2020. Machine learning classifiers for attributing tephra to source volcanoes: An evaluation of methods for Alaska tephras. Journal of Quaternary Science 35, 81-92. DOI: 10.1002/jqs.3170

(Inter)national contacts

VLIZ is at the nexus of various large (data) science projects and, as such, has an extensive network of both national and international partners. Most relevant to TURBEAMS is our involvement in the

LifeWatch-ERIC (E-Science European Infrastructure for Biodiversity and Ecosystem Research, www.lifewatch.eu), in which monthly optical turbidity measurements are carried out.
Within the acoustic research community, VLIZ has good relations with following institutes (and contacts): The University of Hull (Steve Simmons), FPS Economy - Continental Shelf Service (Marc Roche & Koen Degrendele), IFREMER (Jean-Marie Augustin) and GEOMAR Helmholtz Centre for Ocean Research Kiel (Jens Greinert, Peter Urban).

Subcontractor: COPCO

The FPS Economy - Continental Shelf Service (COPCO) is closely involved in the integration of multibeam water column measurements in the real-time impact assessment of the sand extraction activities on the Belgian part of the North Sea. COPCO is participating in the project as a non-funded subcontractor to VLIZ, to provide the necessary complementary expertise in several WP's. COPCO will be mentioned separately in the proposal.

Expertise
COPCO is legally responsible for sand extraction in the Belgian part of the North Sea. COPCO's main tasks are: issuing permits, managing extraction concessions, control of extraction and updating the associated legislation. Since 1999, COPCO has carried out regular surveys to control the direct impact of sand extraction on the marine environment using multibeam echosounder (MBES) bathymetry, seabed backscatter and in situ sampling. In addition to this long-time series of seabed acoustic measurements, backscatter measurements of the water column have been carried out regularly for the last 5 years to quantify the sediment plumes associated with sand extraction. Thereby, COPCO can boast the expertise of almost 25 years on MBES calibration, sea acceptance test, data acquisition settings, survey management, hydrographic quality control, data processing and GIS integration. This expertise is enhanced by an in-depth knowledge of the calibration and correction methods that are necessary to derive scientific information from the seabed and water column backscatter data.

Involved scientists
Dr. Marc Roche Geologist, Scientific Advisor. Since 2005, Head of the Continental Shelf Service (COPCO) in the Belgian Federal Public Service Economy, in charge of marine sand extraction management and control on the Belgian part of the North Sea. Surveyor and analyst with 25 years of experience spread over three generations of multibeam echosounders. Expert on multibeam calibration, sea acceptance test, data acquisition settings, survey management, hydrographic quality control, data processing and GIS integration. He has a critical knowledge of multibeam backscatter data, with in-depth knowledge of the calibration and correction methods that are necessary to derive scientific information.
Koen Degrendele works as a geographer at the Continental Shelf Service (COPCO) since 1998. As surveyor and analyst, he is strongly involved in the monitoring of the impact and control of the sand extraction activities. His multibeam expertise is mainly focussed on bathymetric data acquisition, processing and cartography, calibration and quality control. He's responsible for the survey design and management of the COPCO activities on the RV Belgica for more than 20 years.

5 most relevant publications

- Wyns, L., **Roche, M.**, Barette, F., Van Lancker, V., **Degrendele, K.**, Hostens, K., De Backer, A.,

2021. Near-field changes in the seabed and associated macrobenthic communities due to marine aggregate extraction on tidal sandbanks: a spatially explicit bio-physical approach considering geological context and extraction regimes. Continental Shelf Research. DOI: 10.1016/j.csr.2021.104546

- Malik, M., Schimel, A.C.G., Masetti, G., **Roche, M.**, Le Deunf, J., Dolan, M.F.J., Beaudoin, J., Augustin, J.-M., Hamilton, T., Parnum, I., 2019. Results from the First Phase of the Seafloor Backscatter Processing Software Inter-Comparison Project. Geosciences 9, 516. DOI: 10.3390/geosciences9120516
- Debese, N., Jacq, J. J., **Degrendele, K.**, **Roche, M.**, Garlan, T., 2018. Osculatory surfaces extraction applied to monitoring of sub-marine sand materials. Marine Geodesy, 41(6), 605-631. DOI: 10.1080/01490419.2018.1509161
- **Roche, M.**, **Degrendele, K.**, Vrignaud, C., Loyer, S., Le Bas, T., Augustin, J. M., Lurton, X., 2018. Control of the repeatability of high frequency multibeam echosounder backscatter by using natural reference areas. Marine Geophysical Research, 39(1), 89-104. DOI: 10.1007/s11001-018-9343-x
- Lucieer, V., **Roche, M.**, **Degrendele, K.**, Malik, M., Dolan, M., Lamarche, G., 2017. User expectations for multibeam echo sounders backscatter strength data-looking back into the future. Marine Geophysical Research, Special Issue: Seafloor Backscatter Data from Swath Mapping Echosounders: from Technological Development to Novel Applications (Vol. 39, No. 1-2). DOI: 10.1007/s11001-017-9316-5

Relevant projects

- Development of a reference surface for sand extraction, based on the sedimentological, geomorphological and hydrological environment, to limit the environmental impact of the extraction activities on scientifically based criteria. Internal project FPS Economy - Continental Shelf Service in cooperation with RBINS (2016 - 2020).
- BRAIN-be project TILES - Transnational and Integrated Long-term Marine Exploitation Strategies. Call 2012, 01/10/2013 - 31/12/2017. The partnership has relied on an active cooperation with the FPS Economy-Continental Shelf Service. Co-authors of the final report.
- BRAIN-be project INDI67 - Developments of methods to improve the monitoring of MSFD indicators 6 and 7. Call 2014, 15/12/2014 - 15/03/2019. The partnership has relied on an active cooperation FPS Economy-Continental Shelf Service. Co-author of the final report.
- Kwinte reference area project initiated in 2018 and carried out in collaboration with the Flemish Hydrography, RBINS and the Flanders Marine Institute (VLIZ), this project led to the adoption of a reference zone for the calibration of hydroacoustic sensors. This area is implemented in the Marine Space Plan (2020-2026) (https://www.agentschapmdk.be/nl/akoestische-referentiezone-kwinte).

International contacts

The FPS Economy - Continental Shelf Service network revolves around the use of hydroacoustic instruments for seabed habitat and water column monitoring. The particularly solid link with the Underwater Acoustics and Information Processing Department of IFREMER (Jean-Marie Augustin, Ridha Fezzani and Laurent Berger) deserves to be underlined. As a logical consequence of our core-business focused on the acquisition of acoustic data at sea, regular links are established with SHOM

(Christophe Vrignaud, Sebastien Beuchard, Olivier Morio and Julien Simon), ENSTA Bretagne (N. Debèse), GEOMAR (Jens Greinert), Kongsberg Maritime (Kjetill Jensen, Oystein Aasbo, Kjell Nilsen) and QPS (Jonathan Beaudouin).

Ghent University - Department of Geology and Department of Data-Analysis and Mathematical Modelling

Ghent University's Department of Geology, through the Renard Center for Marine Geology, has decades of experience in acoustic marine surveys in various environments. Since 2017, Thomas Hermans has joined the department in the Laboratory for Applied Geology and Hydrogeology, developing a new research line in geostatistics and geophysical data integration. For the purpose of TURBEAMS, the Department of Geology has joined forces with Stijn Luca from the Department of Data-Analysis and Mathematical Modelling. Stijn Luca has 15 years of theoretical and practical experience in statistical modelling, machine learning and artificial intelligence. Through his experience in life sciences applications, he will bring relevant expertise for similar challenges encountered in Marine Sciences, such as accounting for spatial correlation. This combined marine, geophysical, geostatistical and machine learning expertise makes this UGent consortium the perfect partner for this proposal.

Coordinator: Prof. Dr. Ir. Thomas Hermans

Prof. Thomas Hermans (7 April 1987) is professor in hydrogeology and applied geophysics at the Department of Geology from Ghent University since October 2017, after postdoc positions at Liege University and Stanford University (USA). He obtained a master in geological engineering in 2010, and a PhD in Applied Geophysics in 2014 from Liege University. He has published 38 A1 publications, 3 A2 publications and two book chapters (h-index 17). During his PhD, he worked on the development of a geostatistical framework to integrate geophysical data into groundwater models. Through this research, he gained first-hand experience with multivariate geophysical data sets, dimension reduction techniques, statistical and machine learning approaches. After his PhD, he joined Stanford University where he contributed to the development of Bayesian Evidential Learning and its extension to geophysical data. Since 2017, he is leading his own research group in hydrogeophysics, focusing on three main topics: saltwater intrusions in coastal areas and at the interface between land and sea, advanced processing and inversion tools in geophysics and development of Bayesian Evidential Learning. He is currently supervising 7 PhD students (+ 1 recently graduated). He secured about 1M€ external funding through interdisciplinary project writing.

ORCID: https://orcid.org/0000-0001-9522-1540

Collaborator: Prof. Dr. Marc De Batist

Prof. Marc De Batist (4 June 1960) is full professor in marine and sedimentary geology at the Department of Geology of Ghent University. He is currently also the Head of the Renard Centre of Marine Geology (RCMG), which has been spearheading marine geological and geophysical research in Belgium since the late 1970s. He has published nearly 200 A1 publications (h-index 43) and obtained research funding for nearly 70 projects, of which 17 EU-funded, on topics ranging from marine geology over seismic sequence stratigraphy, basin evolution, paleoseismology, paleoclimatology, marine geoarcheology, marine geohazards, Quaternary geology to gas hydrates and gas seeps. He has extensive expertise in the application of seismic as well as geo- and hydro-acoustic methods in marine as well as lacustrine settings. His current research is focussing on i) Quaternary geology and geoarcheology of the North Sea, ii) lacustrine paleoseismology, and iii) geohazards in general (https://rcmg.ugent.be/geohazards/).

ORCID: https://orcid.org/0000-0002-1625-2080

Collaborator: Prof. Dr. Stijn Luca

Stijn Luca holds a MSc in Mathematics from KU Leuven (Belgium, 2003) and a PhD in mathematics from Hasselt University (Belgium, 2007). Currently, he is an assistant professor at the Department of Data Analysis and Mathematical Modelling of the Faculty of Bioscience Engineering at Ghent University (Belgium). Previously, he was a postdoctoral fellow at KU Leuven (Belgium) and a visiting scholar at the University of Oxford (2014-2015). His research studies the statistical challenges associated with machine learning and artificial intelligence applications in life sciences. He has published 26 A1 publications, one book chapter and 6 WOS-indexed conference papers. He's currently supervising 10 Phd students on the development of data analysis methods applied to a variety of life science applications such as spatial biodiversity monitoring, study of spatial (climate) extremes and species recognition among others. During his career he secured the funding of more than 1M€ through various national and international funding schemes.

ORCID: https://orcid.org/0000-0002-6781-7870

Collaborator: Peter Urban

Peter Urban (7 July 1986) holds a diploma (equivalent to MSc) in electrical engineering from the University of Rostock (Germany, 2013). He is currently finishing his PhD within the Deep Sea Monitoring Group at GEOMAR, Helmholtz-Center for Ocean Research in Kiel, Germany. His PhD thesis focuses on using multibeam water column data for quantitative estimates of underwater gas bubble streams and resulted so far in one peer-reviewed publication (two more in preparation), several conference contributions and numerous (unpublished) c++/python tools. During 11 research cruises on 10 different international vessels, he gained invaluable scientific experience with a large set of different acoustic systems for quantitative investigations of the water column (including various multibeam systems, EK80 and EK60 single beams, ADCPs). Furthermore, he was involved in two projects that aimed at investigating sediment using active acoustic systems.

ORCID: https://orcid.org/0000-0002-0597-7772

Relevant projects

- A new framework for Experimental Design in Earth Sciences using Bayesian Evidential Learning (BEL4ED) (200000 €, UGent – Starting Grant, 2019-2023)
- A new Bayesian framework for Imaging the Subsurface and associated HydrOdynamic Processes (BISHOP) (48 person-months + 10000 €, FNRS, 2018-2022)
- Imaging the fresh/saltwater interface across the Belgian shoreline (ImSalt) (38500 €, FWO – research credit, 2019-2021, 25000 €, KBS – Fonds Van Autenboer, 2020-2023)
- Dumpsites of munitions: Integrated Science Approach to Risk and Management (DISARM)

(2 520 810 € - total budget, FWO SBO project, 2020-2023)

5 most relevant publications

- **Hermans, T.**, Nguyen, F., Klepikova, M., Dassargues, A., Caers, J., 2018. Uncertainty quantification of medium-term heat storage from short-term geophysical experiments using Bayesian Evidential Learning. Water Resources Research 54, 2931–2948. DOI: 10.1002/ 2017WR022135
- Michel, H., Nguyen, F., Kremer, T., Elen, A., **Hermans, T.**, 2020. 1D geological imaging of the subsurface from geophysical data with Bayesian Evidential Learning. Computers & Geosciences 138, 104456. DOI: 10.1016/j.cageo.2020.104456
- Veloso, M., **De Batist, M.**, Mienert, J., Greinert, J., 2015. A new methodology for quantifying bubble flow rates in deep water using splitbeam echosounders: Examples from the Arctic offshore NW- Svalbard. Limnology and Oceanography: Methods 13(6), 267–287. DOI: 10.1002/lom3.10024
- **Urban, P.**, Köser, K., Greinert, J., 2017. Processing of multibeam water column image data for automated bubble/seep detection and repeated mapping. Limnol. Oceanogr. Methods, 15: 1-21. DOI: 10.1002/lom3.10138
- **Luca, S.**, Pimentel, M.A.F., Watkinson, P.J., Clifon, D.A., 2018. Point process models for novelty detection on spatial point patterns and their extremes. Computational statistics & data analysis 125, 86-103. DOI: 10.1016/j.csda.2018.03.019

(Inter)national contacts

The Department of Geology (Ghent University) has decades of experience with acoustic marine surveys onboard international research vessels and has been involved in multibeam water column research for over a decade around the world (Marc De Batist). Through Thomas Hermans, the department has also extensive experience in geophysical data integration (International thematic network - PROSPECT), geostatistics and machine learning with ongoing collaborations with Stanford University (Jef Caers) and Liege University (Frédéric Nguyen). A close collaboration also exists for waterborne surveys with the Technical University of Vienne (Adrian Flores-Orozco). The Department of Data Analysis and Mathematical Modelling has an extensive network with other data-analysis and statistical research groups (Stijn Luca). There is an extensive collaboration with University of Oxford's Machine Learning group of David Clifton and there are ongoing collaborations with the Department of Statistics at Stellenbosch University (joint-PhD). Peter Urban, through his past research experience, has privileged links with GEOMAR in the Department of Geosystems.

RBINS

The Royal Belgian Institute of Natural Sciences (RBINS) is a Belgian Federal State Institution governed by the Belgian Science Policy Office (BELSPO). Besides its significant multidisciplinary research activities, it hosts the Museum of Natural Sciences and collections of specimens and provides public services in terms of advice, expertise and studies. The mission of its Operational Directorate “Natural Environment” (OD Nature) is to support the management of the marine environment, particularly for Belgian waters, by scientific activities including mathematical modelling, measurements and advice to policy-makers.

Coordinator: Dr. Matthias Baeye

Matthias Baeye is a senior scientist specialized in the effects of human activities on the fine-grained sediment concentration and transport. He holds a PhD in sedimentology (Ghent University, 2012), has worked on the conversion of acoustic backscatter signals from ADCP and multibeam towards SPM concentration and on the effects of SPM composition on the inherent acoustic and optical particle properties of the SPM.

Collaborator: Prof. Dr. Vera Van Lancker

Vera Van Lancker (PhD UGent, Belgium) is a marine geologist. For nearly 30 years, she has conducted and supervised marine research projects (e.g., related to geological resources, seabed habitats, biogeomorphology, sediment dynamics, and the impact of human activities), targeting more sustainable exploitation of marine environments. Coordinator of nationally funded projects and task leader in international projects. Responsible for the design and implementation of the monitoring of sand extraction and seafloor integrity (Marine Strategy Framework Directive). Actively involved in the valorization of geological and geophysical data for a wide user community. Member of international advisory boards. Teaching and research professor at Ghent University, Department of Geology.

ORCID: https://orcid.org/0000-0002-8088-9713

Collaborator: Dr. Michael Fettweis

Michael Fettweis is specialized in measurements, data analysis and numerical modelling of fine-grained particle movements. In 2019 he received the Mehta award for outstanding achievements related to the transport of particulate matter in shallow coastal seas and estuaries (http://www.intercoh.org/post/mehta.award/). He was chief scientist on about 100 campaigns with the RV Belgica (from 1999 onward) and is the scientific coordinator of the coastal observatory at MOW1 (Belgian nearshore area) and of the RBINS monitoring program BGCMonit. His research focuses on the natural variability of fine-grained sediment transport due to geophysical and biological processes in shallow highly dynamic coastal seas, on the particulate and dissolved matter fluxes in coastal seas and in the deep sea driven by natural processes, human impacts and climate change and on the development of monitoring strategies and indicators for the evaluation of Good Environmental Status in the framework of the EU MFSD.

ORCID: https://orcid.org/0000-0001-8845-6464

5 most relevant publications

- **Baeye M, Fettweis M,** Voulgaris G, **Van Lancker V.**, 2011**.** Sediment mobility in response to tidal and wind-driven flows along the Belgian inner shelf, southern North Sea. Ocean Dynamics 61, 611-622. DOI:10.1007/s10236-010-0370-7
- **Baeye M, Fettweis M**., 2015. In situ observations of suspended particulate matter plumes at an offshore wind farm. Geo-Marine Letters 35, 247-255. DOI: 10.1007/s00367-015-0404-8
- **Fettweis M,** Riethmüller R, Verney R, Becker M, **Backers J, Baeye M**, et al., 2019.

Uncertainties associated with in situ long-term observations of suspended particulate matter concentration using optical and acoustic sensors. Progress in Oceanography 178, 102162. DOI: 10.1016/j.pocean.2019.102162

- **Montereale-Gavazzi, G**., Roche, M., Degrendele, K., Lurton, X., Terseleer, N., **Baeye, M**., ... & **Van Lancker, V**., 2019. Insights into the short-term tidal variability of multibeam backscatter from field experiments on different seafloor types. Geosciences, 9(1), 34.DOI: 10.3390/geosciences9010034
- **Van Lancker, V**., & **Baeye, M**., 2015. Wave glider monitoring of sediment transport and dredge plumes in a shallow marine sandbank environment. PloS one, 10(6), e0128948. DOI: 10.1371/journal.pone.0128948

Relevant projects

- **ABioGrad** (2022-2032) Abiotic and Biotic sediment dynamics along estuarine-marine Gradients in times of global change. Funded by the Belgian Science Policy within the FED-tWIN programme
- **BGPart** (2021-2024) BioGeochemical PARTicle interactions and feedback loops on the Belgian Continental Shelf). Funded by the Belgian Science Policy
- **MOMO** (2004 onward) Mud transport modelling and monitoring on the Belgian Continental Shelf. Funded by the Ministry of the Flemish Community.
- **JERICHO-S3** (2020-2022) H2020 project funded by the EU.
- **INDI67** (2015-2019) Developments of methods to improve the monitoring of MSFD indicators 6 and 7, funded by BELSPO (BR/143/A2/INDI67).
- **JPIO** (2015-2017) Pilot Action "Ecological aspects of deep-sea mining", funded by BELSPO.
- **ZAGRI/MOZ4** (- onward) Monitoring of hydrodynamics and sediment transport to evaluate the effects of the exploitation of non-living resources of the territorial sea and the continental shelf. Private revenues/Flemish Authorities, respectively.
- **EMODnet-Geology** (Phase 1-5: 2009 -). European Marine Data and Observation Network-Lot Geology. EU DG MARE (EASME/EMFF/2020/3.1.11 - Lot 2/SI2.853812)

(Inter)national contacts

National contacts regarding policy include FPS Environment, DG Environment, Service Marine Environment (Marie-Christine Lahaye, Saskia Van Gaever, Wendy Bonne). **International contacts** in the context of the proposal include Alexander Bartholomä (Senckenberg Institute), Henko de Stigter (NIOZ), Jens Greinert (GEOMAR, Helmholtz Centre for Ocean Research, Kiel), Steve Simmons (Hull University), Bart Vermeulen (Wageningen University), George Voulgaris (University of South Carolina); Michael Fettweis is leading a working group on measuring and interpretation of particle dynamics, which includes (amongst others) Rolf Riethmüller (Helmholtz Centre Hereon), Markus Schartau (GEOMAR, Helmholtz Centre for Ocean Research, Kiel), Romaric Verney (Ifremer, Brest), Byung Joon Lee (Kyungpook National University, South Korea).

4.1.2. Adequacy and added value of the partnership in addressing the topic (max. 1.5 pages)

Fulfilling the objectives in TURBEAMS requires an **interdisciplinary cooperation** between scientists specialized in the fields of plankton research, sedimentology, acoustics and big data statistics. Moreover, a combination of marine surveying and acquisition expertise (VLIZ, RBINS and UGent), multibeam water column processing knowhow (VLIZ, UGent) and competence in big data analysis (UGent) is pivotal to answer the questions raised in the proposal. We believe that the complementary expertise of the present partnership of leading Belgian experts meets these demands and will enable us to successfully achieve the ambitious goals of the TURBEAMS project.

VLIZ manages and deploys a large array of (experimental) infrastructures, including the necessary sensors to measure turbidity/SPM (such as the LISST-200X and the VPR). Thanks to the LifeWatch project, which organizes monthly optical turbidity and plankton measurements, and the TIMBERS project, in which 3D acoustic turbidity is assessed through integration of multibeam and in-situ measurements, VLIZ can assure the required survey and multi-sensor acquisition experience. Additionally, in recent years, VLIZ gathered extensive expertise in multibeam water column acquisition and processing through the TIMBERS project and projects related to volcanic degassing at Laacher See (Germany). Furthermore, as a non-funded subcontractor to VLIZ, **COPCO** also provides the necessary complementary expertise in the calibration and correction methods that are necessary to derive scientific information from the water column backscatter data.

The **Department of Geology** (Ghent University) has decades of experience with acoustic marine surveys onboard (inter)national research vessels and has been involved in multibeam water column research for over a decade, mainly in detection of gas flares in volcanic regions (Marc De Batist). These research topics involved designing novel scripts to load, process and visualize the water column data for these purposes. Additionally, the department (through Thomas Hermans) has ample experience with geostatistics and machine learning approaches and contributed to the development of Bayesian Evidential Learning in geophysical applications, a necessary tool to unravel the relationship between multibeam and in-situ sensor data to the next level.

The collaboration with the **Department of Data Analysis and Mathematical Modelling** (Ghent University, Stijn Luca) will assure the necessary statistical expertise. The department has a broad expertise in the fields of statistics, machine learning, mathematical modelling & bioinformatics. Its research covers the entire data-to-decision workflow ranging from an (optimal) experimental setup for data collection, over data analysis and mathematical modelling, to the use of such models to answer (research) questions. The department works on a variety of application domains in the life sciences such as ecological and environmental monitoring, water purification and raw material recovery and citizen science. The department (through Stijn Luca) has expertise in the statistical & numerical properties of today’s machine learning and artificial intelligence algorithms, which will be essential to adequately analyse the large datasets that the project will generate with various sensors during multiple campaigns.

RBINS developed ample experience in studying sediment and organic matter dynamics within the BPNS, through long-term and high-frequency monitoring campaigns with various sensors (CTD, LISST, Niskin samples, ADCP). Specifically, relevant for TURBEAMS is their expertise with ADCP measurements and processing, which is complementary to the skillset brought forward by the other partners. Additionally, RBINS is the leading expert when it comes to in-situ measurements of SPM within the BPNS.

An additional important aspect is the **follow-up committee**, which brings together experts in acoustic detection, water column particles, SPM and statistical analysis of big datasets. Their continuous feedback and critical assessments will be a great asset to the project, ensuring efficient workflows and faster progress throughout the project.

With this network, combining federal (RBINS), regional (VLIZ) and academic (UGent) research institutions, all facilities and technical requirements (equipment, processing capabilities, numerical modelling skills) as well as the scientific, academic and experimental expertise necessary for the successful completion of the project are available. All three partners already collaborated successfully (e.g. BELSPO projects 4DEMON, HYPERMAQ) and are working together on ongoing projects (e.g. BELSPO BG-PART). All partners have published with at least one other partner in peer-reviewed journals, ensuring smooth and efficient collaboration during the project.

4.2. Gender (max 0.5 page)

TURBEAMS gathers the Belgian experts required to address its specific hypotheses. For VLIZ and RBINS, a combination of men and women will be responsible for the execution of and guidance during the project. By chance, for UGent, all involved researchers are male. However, all involved institutions regard gender equality of the highest priority and during the selection process of the candidates. Consequently, gender neutral recruitment and selection procedures are assured. The only criterion for recruitment is excellence, irrespective of gender and diversity.

4.3. Detailed description of the work plan

4.3.1. Detailed description of the work plan (max. 0.5 pages/WP)

The following Table 1 best visualizes the work packages, tasks and deliverables identified within TURBEAMS. The first five WP’s have been discussed in detail in the methodology section. The foreseen amount of person months (both financed and in kind) related to each task have been added as additional information.

Table 1 : Description of the work plan

Detailed description work plan — *PMs for each task; Fin = financed, IK = In kind*

WP		Timing	Lead	Participants	Deliverable		Timing	PM (FIN/IK) VLIZ		RBINS		UGent		Means	Publications
WP1	**Data acquisition & processing**		**RBINS**					**22**	**18**	**18**	**3**	**2**	**0**		Scient. journal
Task 1.1	Calibration Multibeam	Y1	VLIZ	VLIZ	D1.1.1	calibrated beams for EM2040, BScorr file(s)	M6	2	7		1			*4	
Task 1.2	3D acoustic data	Y1-Y3	VLIZ	VLIZ-UGENT	D1.2.1	Seasonal datasets of georeferenced 3D acoustic data *1	M39	16	8					*4	
Task 1.3	2D acoustic data	Y1-Y3	RBINS	All	D1.3.1	Seasonal datasets of georeferenced 2D acoustic data *1	M39		2	**9**	**1**	**2**		*4	
Task 1.4	1D/2D in-situ turbidity and SPM data	Y1-Y3	RBINS	RBINS-VLIZ	D1.4.1	Seasonal dataset of georeferenced turbidity & SPM parameters *1	M39	4	1	**9**	1			*4	
WP2	**Determine SPM characteristics**		**VLIZ**					**10**	**2**	**6**	**1**	**0**	**0**		
Task 2.1	Determine SPM types and sizes	Y1-Y4	VLIZ	VLIZ	D2.1.1	Detection method SPM types and sizes	M13	8	2					*4	Scient. journal
				VLIZ	D2.1.2	Seasonal dataset of georeferenced SPM types and sizes *1	M42								
Task 2.2	Determine SPM concentration	Y1-Y3	RBINS	RBINS-VLIZ	D2.2.1	Seasonal dataset of georeferenced SPM concentrations *1	M39	**2**		**6**	**1**			*4	
WP3	**Quantifying the relation multibeam water column - turbidity or SPM data**		**UGent**					**1**	**1**	**1**	**0**	**7**	**2**		
Task 3.1	Compile all datasets	Y1-Y4	VLIZ	VLIZ-RBINS	D3.1.1	Compilation dataset	M42	1	1	**1**				*4	
Task 3.2	Establish the optimal relationships	Y1-Y4	UGent	UGent	D3.2.1	(Optimized) relationships	M42					7	2	*4	Scient. journal
WP4	**Developing multibeam water column processing software**		**UGent**					**6**	**0**	**0**	**0**	**26**	**0**		
Task 4.1	Develop a multibeam water column processing library	Y1-Y4	UGent	UGENT	D4.1.1	Finished core functionality	M48					10		*4	
Task 4.2	Create data processing pipelines for the work packages	Y2-Y4	UGent	UGENT	D4.2.1	Multibeam processing pipelines	M48					10		*4	
Task 4.3	Turbidity module: integrate turbidity and SPM estimation equations	Y3-Y4	UGent	UGENT-VLIZ	D4.3.1	3D turbidity/SPM estimates	M48	6				6		*4	Scient. journal
WP5	**Scientific analysis of acoustic and optical backscatter data on the BPNS**		**RBINS**					**0**	**0**	**18**	**3**	**0**	**0**		
Task 5.1	Small-scale variability of SPM concentration	Y1-Y4	RBINS	RBINS	D5.1.1	Natural variability of SPM concentration using multibeam	M48			**6**	1			*4	Scient. journal
				RBINS	D5.1.2	Variability of lower resolution sensors and multibeam	M48								
Task 5.2	Seasonal variation SPM characteristics along a near- to offshore transect	Y1-Y4	RBINS	RBINS	D5.2.1	Seasonal changes in SPM concentration and composition	M48			**6**	1			*4	Scient. journal
Task 5.3	SPM concentration in the benthic layer	Y3-Y4	RBINS	RBINS	D5.3.1	SPM profiles and quantification of near-bed SPM dynamics	M48			**6**	1				Scient. journal
				RBINS	D5.3.2	Added value of multibeam-derived SPM dynamics	M48							*4	
WP6	**Coordination, project management and reporting**		**VLIZ**					**1**	**7**	**0**	**9**	**1**	**9**		
Task 6.1	Organise kick-off meeting	Y1	VLIZ	VLIZ	D6.1.1	Kick-off meeting	M6		1					/	
Task 6.2	Reporting	Y1-Y4	VLIZ	All	D6.2.1-5	Initial report, yearly activity reports & final report	Yearly	1	2		3	**1**	3	/	
Task 6.3	Monthly partners meeting	Y1-Y4	VLIZ	All	D6.3.1	Partner meetings	Monthly		2		3		3	/	
Task 6.4	Yearly general meeting (with follow-up committee)	Y1-Y4	VLIZ	All	D6.4.1-4	General meetings	Yearly		2		3		3	/	
WP7	**Data management**		**VLIZ**					**2**	**2**	**0**	**0**	**0**	**0**		
Task 7.1	Gathering and formatting of the data	Y1-Y4	VLIZ	All	D7.1.1	Formatted data, backup-ready	M48	2	1					*5	
Task 7.2	Storage, backup and DOI attribution	Y1-Y4	VLIZ	VLIZ	D7.2.1	Backuped data, saved on MDA	M48		1					*5	
WP8	**Valorisation, dissemination and exploitation of results**		**VLIZ**					**6**	**6**	**5**	**1**	**6**	**1**		
Task 8.1	Scientific outreach	Y2-Y4	VLIZ	All	D8.1.1	Scientific publications in peer-reviewed journals	M*2	5	3	5		5		*6	
				All	D8.1.2	Contribution to & attendance of conferences	Once/year								
Task 8.2	Publish scripts and tutorials in open access repositories	Y4	UGent	UGENT	D8.2.1	Publicly available open-access scripts and tutorials	M*3					1		*6	Repositories
Task 8.3	Outreach for the general public	Y1-Y4	VLIZ	All	D8.3.1	Social media posts	Twice/year		1		1		1	*6	
				All	D8.3.2	Outreach activities	Once/year								Grote Rede
Task 8.4	Organise water column symposium	Y4	VLIZ	VLIZ	D8.4.1	Water column symposium	M42	1	2					*6	
								48	36	48	17	42	12		

Clarifications:
*1 - After each campaign, an additional dataset will be acquired and processed
*2 - The publication of the obtained results will be assessed throughout the project. We foresee a number of publications in international peer-reviewed journals (examples are “Remote Sensing”, “Marine Geology” and “Marine Geophysical Research”). From WP1-5 a number of publications are foreseen, which have been indicated in the second to last column of the table.
*3 - Throughout the project, scripts, libraries and tutorials will be shared online as soon as they are finished.
*4 - See respective parts in the Methodology (section 3.2.2)
*5 - See Data Management Plan (section 4.4)
*6 - See Plans to maximize the impact of the project (section 5.4).

4.3.2. Work planning and time schedule: Gantt chart (fill in the Gantt chart)

Leave this section empty.

4.3.3. Implementation risk management (max. 1.5 pages)

R1: Campaign issues (Tasks 1.1-1.4)

Marine surveys always have the possibility of being cut short or completely cancelled due to adverse weather conditions. This is inherent to marine research. However, since several multi-day campaigns will be requested (two each year), the (partial) loss of one or two campaigns is not project-threatening if the other campaigns can be completed successfully. If several campaigns are cancelled, this might become more problematic. Then, we plan to join the monthly LifeWatch monitoring, conducted by VLIZ with the RV Simon Stevin. The RV Simon Stevin is also equipped with an EM2040, which could be calibrated as well. Joining the monthly LifeWatch turbidity measurements and gathering calibrated EM2040 data from the RV Simon Stevin would mean a good backup for the project, even though not all sensors and devices can be used, which is possible with the RV Belgica.

R2: Acoustic datasets become too large to handle (Task 1.2)

Multibeam water column datasets are typically very large (several GB’s/hour, depending on the ping rate). This may pose risks towards data processing, as both powerful workstations and capable software are required to handle these datasets. Therefore, a ping rate will be chosen that gives the best trade-off between resolution and handling. This will keep the size of the multibeam water column data manageable, yet representative. Additionally, a cut-off in file size will be set during acquisition, keeping the individual files loadable and processable. At the start of the project, a state-of-the-art PC will be bought, ensuring sufficient processing and graphical capabilities. If the PC turns out to be inadequate in terms of processing power, we will apply for the High-Performance Computing facilities at UGent.

R3: Impossible to determine sedimentological vs. biological particle proportions (Task

2.1)

In order to investigate the relative proportion of sedimentological and biological particles within the SPM assemblages, two challenging approaches using the VPR and EK80 will be put to test. When our approach fails, we can still rely on more labour-intensive techniques (Niskin samples, Zooscan, Flowcam).

R4: Statistical methods do not yield meaningful relations (Task 3.2)

Inherent to investigating relationships in big datasets is the possibility of not obtaining meaningful relations between the variables (multibeam water column and in-situ sensor data). Given the tremendous statistical expertise within the project and the already proven connection between water column particles and acoustics, this risk is rather low though. In addition, the proposed methods will account for the inherent uncertainty related to empirical relationships, and provide uncertainty estimates together with their prediction. If the obtained relationships would appear not meaningful, we will (in consultation with the follow-up committee) adapt some of the settings of the sensors and acoustic devices or update the survey strategy in order to overcome this problem.

R5: Sensor-dependent particle detection (Task 3.2)

Inherently coupled to the use of multiple sensors is the fact that different sensors have different particle type and size sensitivities, so particle-detection is sensor-dependent. Optical backscatter systems, for example, are more sensitive to mud particles (<63 µm) and flocs, while acoustic backscatter systems are more responsive to larger sand grains (>63 µm) (Haalboom et al., 2021; Pearson et al., 2021). Furthermore, the backscatter response to different particle sizes relies on the operating frequency of the detection system (lower frequencies detect only larger particles and vice versa; Wilson and Hay, 2015). Although we strongly believe that the use of multiple frequencies will be key in discriminating particle sizes (and maybe even SPM types), it is possible that the frequency range of the shallow-water multibeam EM2040 (200-400 kHz) does not suffice for the detection of a large portion of the smaller-scaled particles. If this is the case, higher frequency (multibeam) systems from VLIZ, e.g. the Norbit WBMS (able to operate at 550 and 700 kHz) and Blueview (900 kHz - 2 MHz), will be implemented in the TURBEAMS toolbox.

R6: New multibeam data processing scripts do not function (in time) (Task 4.1, Task 4.2)

Since the multibeam data are the centrepiece within the TURBEAMS project, it is therefore crucial that these datasets can be adequately processed. As we plan to develop our own scripts and libraries, it might take some time before the processed multibeam datasets are available (as input for other tasks). If this scripting phase takes too long, the remainder of the work may get delayed and the project may not finish in time. However, this risk is severely reduced thanks to the capabilities among the project members and their contacts. UGent has ample experience with scripting and multibeam water column data and through collaboration with Geomar (Peter Urban), the necessary multibeam water column processing knowhow is assured. As a backup option, VLIZ has also experience with the IFREMER software “SonarScope”. Although not having all the desired capabilities and not being extremely user-friendly, SonarScope can yield basic processed datasets. This means that until our own scripts and libraries have been developed, SonarScope can be used to render first results if necessary.

- Table: Risk Likelihood vs. Impact

		IMPACT				
		Negligible	Minor	Moderate	Significant	Severe
LIKELIHOOD	Very likely					
	Likely		R3			
	Possible		R5, R6	R1		
	Unlikely		R4	R2		
	Very unlikely					

COLOUR CODE: Low Low-Medium Medium Medium-High Severe

4.4. Data management plan

4.4.1. Will data be collected, reused and/or generated?

The proposal will …	☒ COLLECT DATA ☒ REUSE EXISTING DATA ☒ GENERATE NEW DATA

Please describe:

- *Which data you will collect/reuse/generate*
- *How data will be collected / from which source it will be reused / how will it be generated*
- *Its content, technical format and estimated volume.*
- *Any existing constraints regarding its use.*

- During each campaign, the following datasets will be collected:
  - Acoustic datasets: multibeam water column (.kmall, estimated volume 5Gb/h), EK80 (.raw, estimated volume several hundreds of Mb/h) and ADCP (suite of data, including .enr, .ens and .enx, estimated volume a few tens of Mb/h) data
  - In-situ sensors: LISST-200X (ascii files, estimated volume several Mb/h), OBS (several Mb/h) and VPR (tifs, estimated volume 1 Gb/h) data
  - Water samples for the analysis of SPM, POC, PON, pigments and TEP concentrations (estimated number of samples 156) will yield excel data files (few Mb/campaign).
- At the start of the project, legacy multibeam data from the BELSPO TIMBERS project will be used (.all and .wcd, precursors of .kmall data) to kick-start the creation of the processing scripts. Also legacy in-situ sensor data (from the VPR, LISST-200X and OBS) will be used for initial calibrations
- All datasets will be processed and georeferenced ascii datasets (XYZ-parameter) will be generated. An example is processed multibeam water column data, which will yield XYZi data (i stands for backscatter values).

4.4.2. How are legal issues handled?

The proposal will use / process / store **personal** data:	☐ YES ☒ NO
*If your answer is **'YES'**: shortly describe the kind of personal data.* *Add the process and reference to your file in your host institution's privacy register.*	
Click here to enter text.	
The work undertaken in the project will possibly result in research data with potential for technology transfer and valorisation:	☐ YES ☒ NO
*If your answer is **'YES'**, your proposal must take into account possible intellectual property issues.* *Explain who will be the owner of the data (who will have the rights to control access).* *Indicate whether there will be intellectual property rights/restrictions for the data you created, and if applicable, describe how these will be managed.*	
Click here to enter text.	
Will agreements with 3rd parties restrict the dissemination or exploitation of the data the project will (re)use:	☐ YES ☒ NO
*If your answer is **'YES'**: explain which data are affected by this agreement* *State the restrictions that are in place.*	
Click here to enter text.	

4.4.3. How is the project data documented?

What documentation will be provided to enable understanding and reuse of the data collected / generated in this project?	
All results and data from the surveys, measurements, analyses and processing will be quality controlled, provided with metadata (e.g. acquisition system, acquisition parameters and, if applicable, processings settings) and stored in the **Marine Data Archive of VLIZ** (http://mda.vliz.be/) and in the **Belgian Marine Data Centre (BMDC) of RBINS** (sample data, see https://metadata.naturalsciences.be), according to the principles of FAIR (Findible, Accessible, Interoperable and reusable, https://www.go-fair.org/fair-principles/).	
Metadata standards will be used:	☒ FOR ALL DATA ☐ FOR SOME DATA ☐ FOR NONE OF THE DATA
• *if your answer is **'for all data'** or **'for some data'**, please describe in detail which standards will be used.* • *if your answer is **'none of the data'**, please state in detail which metadata will be created to make the data easy/easier to find and reuse.*	
Bathymetric and oceanographic data are already stored in MDA (http://mda.vliz.be), accompanied by a suite of metadata. These metadata are freely consultable and contain all relevant fields for external users. The same metadata standards will be used for the data acquired during TURBEAMS, complying with the FAIR principles.	

RBINS will work together with BMDC to make the dataset metadata accessible via the RBINS metadata catalogue, which works with ISO 19115 and will be served via http://metadata.naturalsciences.be.

4.4.4. Data storage and backup during the BELSPO project

The data will be stored in…	☒ Institution Networked Research Storage ☐ OTHER
*If your answer includes '**OTHER**':* • *Specify which storage solutions you will use during the project, in addition to / instead of the institutional networked research storage.* • *Explain the reasons for using these solutions. E.g. because you need more space than offered by your institution; to facilitate data sharing with collaborators; or because your data requires additional security.*	
All data, being raw data resulting from the surveys and processed datasets, will be quality controlled, provided with metadata, and stored in the Marine Data Archive of VLIZ (http://mda.vliz.be/), according to the principles of FAIR. VLIZ hosts the MDA and offers support for an optimal and unlimited use. The data provider or user is free to structure and manage files and folders at its discretion, making use of the functionalities offered by the system. The metadata will be stored in the data system IMIS of VLIZ. The latter is an online information system developed by VLIZ to provide an overview of the marine scientific landscape in Flanders. Information on datasets, publications, persons and institutions is stored in a structured manner in this system. All data in IMIS is subject to the VLIZ Privacy policy. IMIS can be used at institutional level as well as at project level. The quality-controlled data sets of time series of oceanographic parameters will also be transferred to the BMDC. They will store that data in the DITS system, along with the metadata.	
How will the data be backed up?	
Data stored on the MDA will be preserved, even if VLIZ ceases to exist. If that were to happen, data will then be handed over to a similar company, or if no successor is found, data will be handed over to the providers.	
How will data security and protection of sensitive data be taken care of during the research?	☒ Not applicable (there are no sensitive data) ☐ Default security of the institution networked research storage ☐ Additional security measures
*If your answer is **other than 'Not applicable'**: Describe the main risks and how these will be managed.*	
Access to the MDA is regulated through an account-based registration procedure, managed by VLIZ. Authorisation is only given after consulting the project contact persons (either being the coordinator of the project Thomas Vandorpe or the responsible for MDA within VLIZ).	
What are the expected costs for data storage and backup during the project?	

How will these costs be covered?
Costs related to data storage and backup during the project can be covered by the project budget providing these are fully justified and relate to the project.
The costs related to data storage, metadata generation and data backup will be provided in kind by VLIZ. For details, see WP7 and its PM in the work package table (see section 4.3.1).

4.4.5. Data preservation in the long term - after the BELSPO project

All data will be preserved in the long term (at least 10 years)	☒ YES ☐ NO
If your answer is ***'NO'****: clearly describe what data will be preserved long-term and what data will be destroyed for contractual, legal or regulatory purposes, or for physical preservation issues. Indicate how you will decide which data to keep.*	
All results and data from the project will be stored in the Marine Data Archive of VLIZ (http://mda.vliz.be/). The minimum storage time of 10 years will be respected. The development, backup and maintenance of the MDA is an institutional activity of VLIZ. One of the key-activities of the data centre is to offer an efficient tool and support to archive data files and to ensure their long-term existence. If VLIZ ceases to exist or terminates its data-archiving activities, VLIZ shall attempt to transfer the data files to a similar organisation that will continue the agreement with the data provider under similar conditions if possible. If VLIZ does not succeed in finding a similar organisation, VLIZ will organise a transfer of all files to each intellectual property right holder or data provider. The time series data of oceanographic parameters will be transferred to the BMDC who will store them in the DITS system. They will perform data management on the files in order to import them in the IDOD database, to achieve complete storage.	

The data will be archived within…	☒ Institution Networked Research Storage ☐ OTHER
If your answer includes ***'OTHER'****: Specify which storage solutions you will use in the long term, in addition to/instead of the institutional networked research storage. Please explain the reasons for using these solutions.*	
Click here to enter text.	
How will data security and protection of sensitive data be taken care in the long term?	☒ Not applicable (there are no sensitive data) ☐ Default security of the institution networked research storage ☐ Additional security measures
If your answer is ***other than 'Not applicable'****: Describe the main risks and how these will be managed. Inquire with your institution's research support staff whether your intended storage solution meets your institution's data security policy if your research involves sensitive data.*	
Click here to enter text.	

What are the expected costs for data preservation in the long term? How will these costs be covered?
Costs related to data preservation in the long term can be covered by the project budget providing these are fully justified and relate to the project.
Also after the project has finished and as long as MDA continues to exist, the costs related to data storage, metadata generation and data backup will be provided in kind by VLIZ. Costs for long-term preservation of the data in the BMDC are covered by the RBINS.

4.4.6. Data sharing and reuse

Are there any factors restricting or preventing the sharing or reuse of the data (e.g. agreements with 3rd parties):	☐ YES ☒ NO
*If your answer is **'YES'**: explain which data are affected by this agreement.* *State the restrictions that are in place.*	
Click here to enter text.	

Which data will be made available to the public?	☒ ALL ☐ SOME PART ☐ NONE
*If your answer is **'SOME PART'** or **'NONE'**:* • *Indicate the restrictions on the sharing of the data (why can't it be shared)* • *Explain what data sharing agreement will be implemented* • *Explain what actions will be taken to overcome or to minimize restrictions.*	
Click here to enter text.	

Where/how will data be made available to the public?	☐ Open Access repository ☒ In a restricted access repository ☒ Upon request by mail ☐ Other (specify)
*If your answer is **other than 'Open Access repository'**: Indicate where and how access will be provided.*	
VLIZ is an advocate of free data exchange. Data needs to be made available as much as possible for scientific research both on a national and on an international level. VLIZ considers it its core business to facilitate the disclosure of data. Metadata that illustrate the existence of a dataset are always disclosed publicly, unless VLIZ has been explicitly requested not to do so. In the case of TURBEAMS, all metadata will be completely open access, consultable on MDA. In order to obtain the datasets, a request by e-mail has to be made. VLIZ can also provide the opportunity to formalize datasets by assigning a Digital Object Identifier (DOI) to it. Data of the BMDC will be made freely available within the context of data access rule as stated in BMDC's data policy published on the website (http://www.bmdc.be/NODC/policy.xhtml).	

When will data be made available to the public?	☒ As soon as corresponding communication(s) are published ☐ After the project is finished ☐ After the completion of the project (with embargo)
*If your answer is **other than 'as soon as corresponding communication(s) are published'**: Indicate the reasons for the restrictions on the time release of data (embargo periods). For example, to publish, protect intellectual properties, or seek patents.*	
Click here to enter text.	
Who will be able to access the data and under which conditions?	
Everybody will be able to access the metadata on MDA and request the data by email. Data of the BMDC will be made freely available within the context of data access rule as stated in BMDC's data policy published on the website (http://www.bmdc.be/NODC/policy.xhtml).	
Which data will be made available for re-use?	☒ ALL ☐ SOME PART ☐ NONE
*If your answer is **'SOME PART'** or **'NONE'**: Indicate the restrictions on the re-use of the data. Explain what actions could be taken to overcome or to minimize restrictions.*	
Click here to enter text.	
Under what license will be data shared for re-use?	☒ Creative Commons CCO ☐ Creative Commons CC-BY ☐ Other (specify)
*If your answer is **'OTHER'**: Indicate which license will the data have for reuse, and why.*	
Click here to enter text.	
What are the expected costs for data sharing? How will these costs be covered?	
Costs related to data sharing can be covered by the project budget providing these are fully justified and relate to the project.	
No costs are related to data sharing, as this is possible within MDA.	

4.4.7. Responsibilities

Who will be responsible for the data documentation & metadata?
In case of the use of personal data, please note the name and contact data of the concerned data protection officers.
The principal investigator is responsible for data documentation and metadata. These will be stored on MDA.
Who will be responsible for data storage & back up during the project?
Data storage and backup is ensured through MDA, making VLIZ itself responsible. The responsible for MDA at VLIZ will bear the end-responsibility.
Who will be responsible for ensuring data preservation and sharing?

Data preservation and sharing is ensured through MDA, rendering the MDA-team leader responsible.
Who bears the end responsibility for updating & implementing this DMP?
Default response: The Principal Investigator (PI) bears the overall responsibility for updating & implementing this DMP.
The Principal Investigator (PI), Thomas Vandorpe, bears the overall responsibility for updating & implementing this DMP.

5. IMPACT

5.1. Potential impact of the of the proposal in light of the expected outcomes (max 1.5 pages)

The overall goal of the project is to develop a **methodology** which leads to 3D turbidity and SPM imaging based on multibeam water column data. This methodology, which will allow fast (sailing transects), extensive (3D) and accurate (relationship equations and related uncertainty assessment) estimates of turbidity/SPM can be of extreme importance for **survey and dredging companies**. These companies are required to monitor (background) turbidity/SPM before, during and after bottom-disturbing activities, such as monopile installation or sand extraction. Also, **governmental agencies** can benefit from this technique, as they are required to follow-up on sand extraction and the impact on the environment.

During the project, **libraries** intended for multibeam water column data processing, will be continuously improved and uploaded to open-access repositories, like Github. This will allow other users to apply and update them to suit their needs. The online availability of our developed libraries may then enable other **scientists** to perform more cutting-edge research. An example is the investigation of the environmental impact nodule collectors have on the surrounding water column. At present, such impact studies are carried out by installing several moorings and/or tripodes with turbidity and SPM measurement devices attached, accompanied by 2D ADCP transects (de Stigter et al., 2020). In the best case, turbidity/SPM variability can thus be monitored along 2D profiles. However, with multibeam data, a 3D aspect can be added to this research line, which will allow for a better comprehension of the variability of turbidity and/or SPM and consequently, the (human) impact on the environment.

A large suite of **acoustic sensors from the new RV Belgica** will be used during this project. This includes the EM2040, the ME70, the six EK80's, the Workhorse ADCP and the HiPAP system. By intensively using these acoustic devices during the first years the new RV Belgica will be operational, a lot of useful feedback and best practises will be obtained during the project. These will be provided to the **operators of the RV Belgica**, ensuring more efficient and optimal use during ongoing and future research campaigns. Moreover, some of the acoustic sensors will undergo continuous calibrations, ensuring optimally calibrated backscatter values during the project for every user and verified workflows for future calibration practises.

New generation multibeam echosounders with advanced multi-frequency functionalities is the subject of significant developments at a number of manufacturers. Through its multi-instrumental and multi-frequency approach, the results acquired with TURBEAMS will constitute a solid reference for the development of specific functionalities allowing the use of water column data recorded in multi-frequency mode to derive turbidity in real time. TURBEAMS will thus certainly help to create links between **manufacturers** of multibeam echosounders and scientists using this technology and consolidate the existing ones.

5.2. Follow-up committee (max. 2 pages)

The follow-up committee will play a central role within the TURBEAMS project. The suggested members of our committee consist of scientific and industrial actors, all actively involved in acoustic, turbidity and/or statistical research topics or industrial activities. They will be involved in the research project through annual meetings, ad hoc contacts when their advice is wanted and possible attendance during research campaigns. Given the variety of backgrounds of the committee members and their varying degree of involvement, we have specified three different roles:

1. **An active role (involved in research)**. An active role is for those who indicated they want to help out within the project. Steve Simmons showed such interest, by proposing to participate in some of the surveys, as well as helping with data processing afterwards.
2. **A guiding role (consulted)**. A guiding role is assigned to members who have outstanding expertise in one of the involved research fields, but did not explicitly express their interest for involvement during campaigns or data processing. Jens Greinert, who has a long track record of acoustic research and Frederic Nguyen, who has ample experience in applied statistical geophysics, will fulfil such a role. They will provide useful input during the annual meetings (WP6), both in assessing the progress of the past year and in shaping the workflow for the coming year.
3. **A valorisation role (consulted)**. Some of the committee members conduct scientific or industrial activities using similar technologies or approaches. Hence, they may benefit from the results obtained in TURBEAMS. As such, they are the ideal partners to guide the project towards optimal valorisation potential. This is the case for several of our committee members.
    a. Dredging companies DEME and Jan De Nul expressed their interest in the project, given the potential role of multibeam-based SPM monitoring. During the annual meetings, these members can provide useful input on how to optimally develop the methodology, so that post-project industrial applications may be achieved faster.
    b. IMDC, a consultancy company specialized in water research, has a similar line of research running (conversion ADCP data to SPM concentrations), making them the ideal partner for achieving valorisation at the interface between science and industry.

All members bring a different skillset to the TURBEAMS-table, ideal for the implementation and execution of the project. The different members, their institution, sector, role and main activities are summarized below in Table 2.

Table 2: Follow-up committee members

NAME	INSTITUTION	SECTOR	MAIN ACTIVITIES	ROLE
Steve Simmons	University of Hull	Scientific	Acoustics & SPM detection	Involved in research
Lieven Lorentz	DEME	Industrial	Acoustics & turbidity	Guidance & Valorisation
Sam De Coene	Jan De Nul	Industrial	Acoustics & turbidity	Guidance & Valorisation
Jan Claus & Jelle Malschaert	IMDC	Industrial	Acoustics & Water	Guidance
Jens Greinert	GEOMAR	Scientific	Acoustics & turbidity	Guidance
Frederic Nguyen	Université de Liège	Scientific	Geostatistics & Applied geophysics	Guidance

If additional (private) actors indicate the desire to be more actively involved within the project, they can be invited to join the follow-up committee, depending on the approval of BELSPO.

5.3. Follow-up committee member intent (non-mandatory - duplicate the requested information as appropriate)

First and Last name:	Steve Simmons

Gender:	M	☒
	F	☐
	X	☐

Institution and unit:	Energy and Environment Institute, University of Hull, UK

Tel:	+44 7941 550411	Email:	s.simmons@hull.ac.uk

Website:	Click here to enter text.

Describe what aspect(s) of the project is/are of interest to you and why:
I am interested in water column imaging and measurement of sediment in suspension. The project is particularly of interest to me given my previous research into the use of multibeam echosounders for water column imaging of suspended sediment of fluvial processes in large rivers and entrainment of sediment plumes generated by commercial fishing gear. More generally, I have a background in developing methods for inverting acoustic backscatter across a range of scales form the deep ocean to the laboratory and I am keen to support this project because of its ambitious use of different

cutting-edge technologies to acquire, validate and process water column suspended sediment data.
Describe with what information/data/support/... you could contribute to the project:
I am happy to provide support derived from my experience and expertise in converting water column suspended sediment backscatter to sediment concentration. This will take the form of attendance at committee meetings, being available to provide support at other times, and to assist, if possible, in publications arising from the project. If funding is available then I would also like to participate in one of the anticipated cruises.

First and Last name:	Sam de Coene

Gender:	M	☒
	F	☐
	X	☐

Institution and unit:	Jan De Nul – Marine environment department

Tel:	+32 53 731 512	Email:	sam.decoene@jandenul.com

Website:	www.jandenul.com

Describe what aspect(s) of the project is/are of interest to you and why:
I have a background in hydrography and I am currently working with environmental sensors on a daily basis. It would be great to be able to collect high quality reliable turbidity data in 3D with multi beam. This makes it possible to make more accurate turbidity plume models from dredging activities, river discharge and improve turbidity plume studies. I am interested in the process and research, which will be involved to translate 3D multi beam data into the proven data of traditional turbidity meters (1D and 2D) and the research process to eliminate the target ambiguity.
Describe with what information/data/support/... you could contribute to the project:
I started within Jan De Nul as hydrographic surveyor. I worked mainly with single beam (Odom Echotrac) and multi beam (EM2040C, Norbit iWBMS) and (processing) software like AutoClean and AutoPatch which might be relevant for the project. Since last year, I work for the marine environment department (MARED), where I am responsible for the monitoring equipment. This includes real time data buoys, wave buoys, multi parameter probes, ADCP (AWAC, Aquadopp, RDI, Aanderaa ADCP, DCS), weather stations, (under water) sound meters, ... I make sure the units are tested and working before the transport to site and I give technical support to colleagues on site. My contribution to the project can be my experience with the above-mentioned equipment and my interest in the correlation between multi beam data and traditional turbidity meters.

First and Last name:	Jan Claus/ Jelle Malschaert

Gender:	M	☒
	F	☐
	X	☐

Institution and unit:	IMDC nv.

Tel:	+32 3 270 92 95	Email:	jca@imdc.be/jma@imdc.be

Website:	www.imdc.be

Describe what aspect(s) of the project is/are of interest to you and why:
As a marine/dredging consultant IMDC is involved in different aspects of water-related monitoring: acquisition, data-processing, interpretation, modelling, etc. As such turbidity is a very important parameter which is dealt with in our daily projects and a critical factor with regards to environmental and sea/river bed morphological considerations. From IMDC's perspective methods improving/extending turbidity monitoring in space (3D) have a significant potential and could be applied to better assess and understand challenging turbid conditions and impact of turbidity, especially if the information could be deducted as a secondary parameter from existing datasets (multibeam).
Describe with what information/data/support/... you could contribute to the project:
As described IMDC has its own monitoring department and is very familiar with turbidity monitoring. Through past and current projects, we have been performing numerous stationary as well as mobile turbidity measurements for different monitoring purposes. In addition, since 2010 IMDC has continuously been an active monitoring partner in the MONEOS project, researching the impact of the Sigma plan, dredging activities and harbor expansion on the environment of the Sea Scheldt. Part of the monitoring scope for which IMDC is responsible covers the extraction of acoustic data (ADCP) to suspended sediment concentrations (SSC). To further illustrate IMDC's expertise and capability in support of the current project, reference is made to another long-term project of IMDC: Fairway Management (vaarwegbeheer) at the Scheldt River. Within this framework a flexible disposal for the continuous optimization of dredging and disposal activities in the Scheldt Estuary has been followed up. In a recent monitoring campaign multibeam data was combined with SSC-data, derived from mobile ADCP-profiles. As a senior monitoring specialist, project manager of the MONEOS project since 2010 and many other monitoring projects, **Jan Claus** has been involved with turbidity issues from different angles, throughout his whole career. Jan is therefore very well placed to give input towards applications of the knowledge to be developed, formulate critical in-depth questions, bring in expert judgement and support this project in general. As a monitoring specialist and former hydrographic surveyor **Jelle Malschaert** has long experience in the MONEOS project, as well as Fairway Management and numerous other turbidity monitoring campaigns. Jelle is therefore well placed to give input towards applications of the knowledge to be developed, formulate critical in-depth questions and support this project in general.

5.4. Plans to maximise the impact of the project (science and other) (max. 3 pages)

TURBEAMS will generate new insights on the relationship between multi-frequency acoustics and in-situ sensor data and will yield novel, improved software to process multibeam water column data and convert them into turbidity and SPM information. The developed methodology and accompanying software have the potential to drastically increase the spatial coverage of monitoring efforts, which consequently reduces survey time. This ground-breaking aspect is of primary interest for the scientific community, governmental agencies and industrial actors, most of which are represented in the follow-up committee. Other potential beneficiaries are the general public through outreach activities. The potential beneficiaries are grouped into five categories below, along with the actions to reach them.

1. Governmental organisations and policy-makers
    a. BELSPO

The empirical relationships to convert acoustic data into SPM values, developed in TURBEAMS, will be best applicable on the multibeam (EM2040) from the RV Belgica itself. Consequently, all users of the vessel and this multibeam system may benefit from the results of this project, in particular, projects related to turbidity measurements. Consequently, BELSPO may have an additional asset at the end of the project, allowing more high-end research with the RV Belgica. Through the **annual meetings (Task 6.4)**, to which BELSPO will be invited, **annual reports (Task 6.2)** and **peer-reviewed publications (Task 8.1)**, updates on the progress of the project can be followed by BELSPO and disseminated among the scientists of the coming research campaigns.

    b. Continental Shelf Service of FPS Economy (COPCO)

COPCO is tasked with monitoring the impact of sand extraction on the sandbanks and their benthic communities within the BPNS. Currently, they repeatedly survey extraction areas and compare bathymetric and seafloor backscatter maps in order to reveal the changes, and related impact on the benthic communities. However, also the amount of sediment in suspension has a great impact on these benthic communities. Consequently, being able to monitor turbidity/SPM changes based on multibeam technology would be extremely beneficial for these monitoring programs. The results of TURBEAMS can therefore be directly implemented in the survey strategy of COPCO.

    c. Belgian policy

As TURBEAMS is mostly a methodological research project, actors who gather and process their own data will benefit most from the results. However, Belgian policy-makers can make use of the results as well, given additional datasets on turbidity and SPM will be gathered during the project. Both RBINS and VLIZ are situated on the nexus of science and policy. Hence, the results of TURBEAMS will be frequently shared (formally and informally) with our governing, policy-making institutes (e.g. FPS Environment, Flemish government).

2. Scientists

A variety of scientific applications may arise from the results of TURBEAMS. One example has already been discussed before (section 5.1) and relates to the impact nodule collectors have on the deep-sea environment they are designed to work in (de Stigter et al., 2020). 3D multibeam turbidity/SPM monitoring may add a dimension to the monitoring, which may yield additional insights on the dispersion and settling speed of the generated sediment clouds. A second example relates to continental slope research. On large parts of the continental slopes, canyons are present (Harris and Whiteway, 2011), transporting sediment from the shelf to the deeper parts of the ocean (e.g. Amaro et al. 2016). Nowadays, transport within canyons is measured using moorings

and landers, equipped with in-situ sensors, which results in 1D datasets (Haalboom et al. 2021). Multibeam-derived turbidity/SPM information may also reveal a wealth of information in this line of research. Moreover, the developed software within TURBEAMS may prove to kickstart (ongoing) projects that would like to make use of the newly developed methodology.
Consequently, it is vital to inform fellow scientists as much as possible on the progress of TURBEAMS. Therefore, we aim to attend multidisciplinary **scientific conferences, such as EGU (Task 8.1),** where we will disseminate the results to a broader scientific audience. However, we will also participate in more specific workshops, like GeoHab. Furthermore, **papers in open-access journals (Task 8.1)** and the organization of the **multibeam water column symposium (Task 8.4)** are specifically designed to inform the scientific community about the results of TURBEAMS. Experience with organizing such an event is present at VLIZ, who organises the yearly "VLIZ marine science day". Moreover, they also hosted a webinar related to multibeam water column data in 2021. To ensure optimal valorisation towards (future) scientific applications, scientists working in this field of research (e.g. Jens Greinert) have been taken up in the **follow-up committee (Task 6.4)**.

3. Non-governmental agencies

There are a number of non-for-profit organizations (WWF, Natuurpunt, Bond Beter Leefmilieu) that have a strong interest in the North Sea and its ecosystem. Both VLIZ and RBINS maintain communication channels with these NGOs, through which TURBEAMS outcomes will be disseminated.

4. Industrial/private sector

For the companies that are a part of the **follow-up committee** (member intent expressed by Jan De Nul and IMDC), the annual follow-up committee meetings **(Task 6.4)** and other ad-hoc meetings are the ideal platform to distribute the results of TURBEAMS among industrial actors. A second way to disseminate the results is through "**The Blue Cluster**" initiative that VLIZ co-created. A large number of the companies that are currently active in the Blue economic development of Flanders (180 members) are grouped together in this government-supported spearhead cluster. Many of these members attend the annual "**Marine Science meets Maritime Industry" event**, organized by VLIZ. This single-day conference brings together Belgian maritime entrepreneurs and scientists, and has become a marine hotspot to exchange ideas as well as to create networking opportunities. This is the ideal event to disseminate the results of the TURBEAMS project and invite industrial actors to provide feedback. For example, the ongoing TIMBERS project will be presented at this year's event. Major milestones of the project can also be shared through the existing communication channels of the industries' own platforms (e.g. newsletter of The Blue Cluster).

5. General public

Reaching the general public on the results of scientific projects can be more challenging. However, VLIZ has a number of communication channels, allowing us to distribute the project results. First, we aim to be represented at the annual "**Dag van de Wetenschap**" event **(Task 8.3)**, when scientific institutions open their doors for visitors. VLIZ has participated at this event for a number of years and strives to continue this run. The TURBEAMS partners foresee giving demonstrations on how multibeam water column data is acquired and processed. Secondly, intermediate progress results of the project will be shared through the **social media channels** of each partner (see Table 3 below), informing numerous subscribers in a straightforward way **(Task 8.3)**. Finally, towards the end of the project, we aim to **publish** a (Dutch) **article** on multibeam water column and its applications in 'De Grote Rede', a bi-annual free magazine, published by VLIZ, informing a broader audience on marine and coastal related topics.

Table 3 : Social media channels of the partners

[1]	VLIZ		UGent		RBINS	
Twitter	@jmeesvliz	5230	@GeologyUGent	209	@RBINSmuseum	13400
Instagram	VLIZOostende	976	rcmg_on_the_field	124	rbinsmuseum	4546
Facebook	@VLIZnieuws	2610	@GeologieUGent	1170	@museumdino	19549

[1] Situation on 02/09/2021

One additional impact factor that should be mentioned is the publication of data and software codes in **online repositories**. All data gathered during this project will be made available through Marine Data Archive **(Task 7.2)**, while the software codes will be published in open-access libraries like Github **(Task 8.2)**. Especially the potential impact of the latter cannot be underestimated as scientists, industrial actors and others may build on these codes and develop improved products, allowing additional implementations in research and monitoring programs.

6. RESEARCH BUDGET

6.1. Budget overview:

6.1.1. Network project

Consortium budget overview

Double mouse click on table to open the excel sheet

EURO	VLIZ	Ugent	RBINS	**TOTAL**
Staff	330,239	350,789	194,400	**875,428**
General Operation	0	0	19,440	**19,440**
Specific Operation	20,900	11,000	0	**31,900**
Overheads	17,557	18,089	10,692	**46,338**
Equipment	5,500	2,000	0	**7,500**
Subcontracting	0	0	0	**0**
TOTAL	**374,196**	**381,879**	**224,532**	**980,607**

Budget of the coordinator (P1): Thomas Vandorpe (VLIZ)

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EURO	Year 1	Year 2	Year 3	Year 4	TOTAL
Staff	80,724	81,935	83,169	84,411	**330,239**
General Operation					**0**
Specific Operation	3,600	4,100	5,600	7,600	**20,900**
Overheads	4,216	4,302	4,438	4,601	**17,557**
Equipment	5,500	0	/	/	**5,500**
Subcontracting	0	0	0	0	**0**
TOTAL	**94,040**	**90,337**	**93,207**	**96,612**	**374,196**

Budget of Partner 2 (P2): Thomas Hermans (UGent)

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EURO	Year 1	Year 2	Year 3	Year 4	TOTAL
Staff	94,874	97,016	102,797	56,103	**350,789**
General Operation	0	0	0	0	**0**
Specific Operation	2,000	3,500	2,000	3,500	**11,000**
Overheads	4,844	5,026	5,240	2,980	**18,089**
Equipment	2,000		/	/	**2,000**
Subcontracting	0	0	0	0	**0**
TOTAL	**103,717**	**105,542**	**110,037**	**62,583**	**381,879**

Budget of Partner 3 (P3): Matthias Baeye (RBINS)

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EURO	Year 1	Year 2	Year 3	Year 4	TOTAL
Staff	48,600	48,600	48,600	48,600	**194,400**
General Operation	4,860	4,860	4,860	4,860	**19,440**
Specific Operation	0	0	0	0	**0**
Overheads	2,673	2,673	2,673	2,673	**10,692**
Equipment	0	0	/	/	**0**
Subcontracting	0	0	0	0	**0**
TOTAL	**56,133**	**56,133**	**56,133**	**56,133**	**224,532**

6.2. Justification of the requested budget

6.2.1. Budget justification for the Coordinator (single team project and network project) (P1): Thomas Vandorpe (VLIZ)

Staff

Personnel's name (*if known*) and profile (e.g. Name, PhD in economics, 2 years experience)	P/M to be financed	Estimated full time monthly cost	Total Cost	P/M not financed
Nore Praet, PhD in Geology, 7 years experience	48	6880	330239	0
TOTAL	48	6880	330239	0

Specific Operation

Description:	Cost

Licences for software packages Global Mapper (visualization of geographical data) and CorelDraw (figure making for publications, presentations and outreach material) will be requested at the start of the project.	3400
Organization of the kick-off meeting. This meeting is intended for all involved parties, including the follow-up committee. This cost includes travel, catering and venue.	1500
Organization of the yearly meetings. 1000€/ meetings is foreseen, covering the expenses of the venue, catering and travels.	3000
Publications costs. A total of 2 open-access publications, led by VLIZ, are envisaged within this project. To cover the expenses for full open-access publications, 1500€/publications is foreseen.	3000
Conferences. From the second year onwards, results obtained within the project will be disseminated at (inter)national conferences. The budget includes transport, hotel and attendance costs.	6000
Symposium. In the final year of the project, a symposium for all working on and interested in multibeam water column data (processing) will be held at VLIZ, similar to the webinar held in 2021. These costs include venue, catering and invitation of key-note speakers.	2500
Organisation campaigns and maintenance/repair equipment.	1500
TOTAL	20900

Equipment

Description:	Cost
Hach portable turbidimeter 2100Q. The Hach turbidimeter allows the acquisition of fast turbidity measurements at location. All Niskin samples will be analysed with the Hach.	2000
State-of-the-art high-end PC for processing multibeam water column datasets will be acquired. The PC needs adequate memory (loading large datasets) and graphical processing power (3D visualizations of the water column data).	3000
Bearing in mind the large amount of data the project will deal with, additional external hard drive(s) will be bought to take along on campaigns, meetings and conferences.	500
TOTAL	5500

Subcontracting

Name: COPCO Address: Koning Albert II-laan 16, 1000 Brussel	
Description of tasks:	Cost
Click here to enter text.	/

6.2.2. BUDGET JUSTIFICATION FOR PARTNER 2 (P2) (ONLY FOR NETWORK PROJECT): Thomas Hermans (UGent)

Staff

Personnel's name (*if known*) and profile (e.g. Name, PhD in economics, 2 years experience)	P/M to be financed	Estimated full time monthly cost	Total Cost	P/M not financed
Peter Urban, PhD in Geology, 7 years of experience	42	8352	350789	0
TOTAL	42	8352	350789	0

Specific Operation

Description:	Cost
Conferences. Results obtained within the project will be disseminated at (inter)national conferences. The budget includes transport, hotel and attendance costs.	8000
Publications costs. A total of 2 open-access publications, led by UGent, are envisaged within this project. To cover the expenses for full open-access publications, 1500€/publications is foreseen.	3000
TOTAL	11000

Equipment

Description:	Cost
High-end PC allowing to develop and test processing scripts for multibeam water column datasets. The PC needs adequate memory (loading large datasets) and graphical processing power (3D visualizations of the water column data).	2000
TOTAL	2000

6.2.3. BUDGET JUSTIFICATION FOR PARTNER 3 (P3) (ONLY FOR NETWORK PROJECT): MATTHIAS BAEYE (RBINS)

Staff

Personnel's name (*if known*) and profile (e.g. Name, PhD in economics, 2 years experience)	P/M to be financed	Estimated full time monthly cost	Total Cost	P/M not financed
NN, MSc in Geology/Biology, 0 years of experience	48	4050	194400	0
TOTAL	48	4050	194400	0

Specific Operation

Description:	Cost
TOTAL	0

Equipment

Description:	Cost
TOTAL	0