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Contribution to Sensor Validation and Oceanographic Data Collection Campaigns

immersion inside a research team

MarSens
MARINE OPTICS & REMOTE SENSING

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Abstract

Résumé Ce stage a été réalisé au sein du laboratoire Marine Optics and Remote Sensing (MARSENS) de l'Université de Gand (UGent). Les travaux du laboratoire portent sur l'étude du cycle du carbone océanique à l'aide de techniques d'optique marine, de télédétection et d'instrumentation autonome. L'objectif principal du stage était de contribuer à la préparation et à la réalisation d'une campagne océanographique dédiée notamment à la validation du capteur LISST-PIC, un instrument innovant développé pour mesurer les concentrations de carbone inorganique particulaire (PIC) dans l'océan. Les activités réalisées ont couvert des aspects variés allant de la conception mécanique d'équipements scientifiques à la participation aux opérations en mer, en passant par le traitement de données et l'analyse bibliographique. Une part importante du travail a concerné la conception d'une cage instrumentée destinée au déploiement simultané de plusieurs capteurs optiques jusqu'à 2000 m de profondeur lors d'une campagne à bord du navire océanographique Belgica. Le stage a également permis de participer à la conférence internationale Ocean Optics XXVII. Cette expérience a offert l'opportunité de contribuer à l'organisation de l'événement, d'échanger avec des chercheurs du domaine et de découvrir les avancées récentes en optique marine, télédétection et instrumentation océanographique. Au-delà des aspects techniques, ce stage a permis de découvrir le fonctionnement quotidien d'une équipe de recherche en océanographie, les contraintes associées aux campagnes scientifiques et les enjeux actuels liés à l'observation du cycle marin du carbone.

Abstract

Abstract This internship was carried out within the Marine Optics and Remote Sensing (MARSENS) laboratory at Ghent University. The group develops innovative optical instruments and observation methods to improve the understanding of marine biogeochemical processes and the ocean carbon cycle. The main objective of the internship was to contribute to the preparation and execution of an oceanographic campaign supporting the field validation of the LISST-PIC sensor, an instrument specifically designed to measure particulate inorganic carbon concentrations in seawater. The work performed involved engineering activities, field operations, data processing and scientific literature review. A major part of the internship focused on the design and preparation of an instrument cage intended to support multiple optical sensors during deployments down to 2000 m depth aboard the research vessel Belgica. In addition to research activities, the internship provided the opportunity to participate in the Ocean Optics XXVII conference, one of the leading international conferences dedicated to marine optics and ocean-colour remote sensing. Contributing to the organisation of the event and interacting with researchers from around the world provided valuable exposure to the international scientific community. Beyond technical contributions, this internship provided valuable experience in marine optics, oceanographic field work, scientific instrumentation and multidisciplinary research related to the marine carbon cycle.

Introduction

The ocean contains approximately 38 000 PgC of carbon and represents the largest active carbon reservoir involved in exchanges with the atmosphere. Human activities currently emit about 10 PgC of carbon per year, of which approximately one quarter is absorbed by the ocean [**?**]. Understanding the mechanisms controlling carbon uptake, transformation and storage within marine environments has therefore become a major scientific challenge. Among the processes involved in marine carbon sequestration, the Biological Carbon Pump plays a central role. Through the activity of phytoplankton and other marine organisms, carbon is transferred from surface waters toward the deep ocean, where it can remain isolated from the atmosphere for decades to centuries. While the export of organic carbon has been extensively studied, significant uncertainties remain regarding the production, distribution and export of particulate inorganic carbon (PIC), mainly produced by marine calcifying organisms such as coccolithophores. These uncertainties largely originate from the difficulty of measuring PIC in situ. Traditional methods rely on water sampling and laboratory analyses, limiting both the spatial and temporal resolution of observations. Developing autonomous technologies capable of continuously monitoring PIC concentrations therefore represents an important objective for modern oceanography. Within this context, the Marine Optics and Remote Sensing (MARSENS) laboratory at Ghent University develops innovative optical technologies aimed at improving observations of marine particles and carbon cycling processes. One of the most recent developments of the laboratory is the LISST-PIC sensor, a novel optical instrument designed to measure particulate inorganic carbon autonomously by exploiting the birefringence properties of calcium carbonate particles. The objective of this internship was to contribute to the preparation and execution of a field campaign intended to validate the LISST-PIC under realistic oceanographic conditions. The internship also provided the opportunity to participate in the Ocean Optics XXVII conference, one of the most important international conferences dedicated to marine optics and ocean-colour remote sensing, offering direct exposure to the broader scientific community working on marine observations and optical technologies. This report is divided into three chapters. The first chapter introduces the scientific concepts required to understand the project, including marine carbon cycling and optical oceanography. The second chapter presents the scientific objectives of the LISST-PIC validation effort and the Belgica campaign. Finally, the third chapter describes the activities performed during the internship and discusses their contribution to the overall project.

Presentation of the Scientific Context

2.1 The Ocean Carbon Cycle

Carbon continuously circulates between the atmosphere, oceans, biosphere and lithosphere through a complex set of physical, chemical and biological processes. The ocean contains approximately 38 000 PgC of carbon, making it the largest active reservoir of carbon involved in exchanges with the atmosphere [**?**]. In seawater, carbon exists in several forms. Dissolved inorganic carbon (DIC), composed of dissolved carbon dioxide, bicarbonate ions and carbonate ions, represents by far the largest marine carbon reservoir. Global DIC stocks are estimated at approximately 38 000 PgC. Dissolved organic carbon (DOC) accounts for approximately 700 PgC, while particulate organic carbon (POC) and particulate inorganic carbon (PIC) are much smaller reservoirs, estimated at approximately 30 PgC and less than 10 PgC respectively [**?**]. The different forms of dissolved inorganic carbon are linked through chemical equilibria:

$$CO_2 + H_2O \leftrightarrow H_2CO_3$$

$$H_2CO_3 \leftrightarrow HCO_3^- + H^+$$

$$HCO_3^- \leftrightarrow CO_3^{2-} + H^+$$

These reactions regulate seawater pH and control the availability of carbonate ions required for marine calcification.

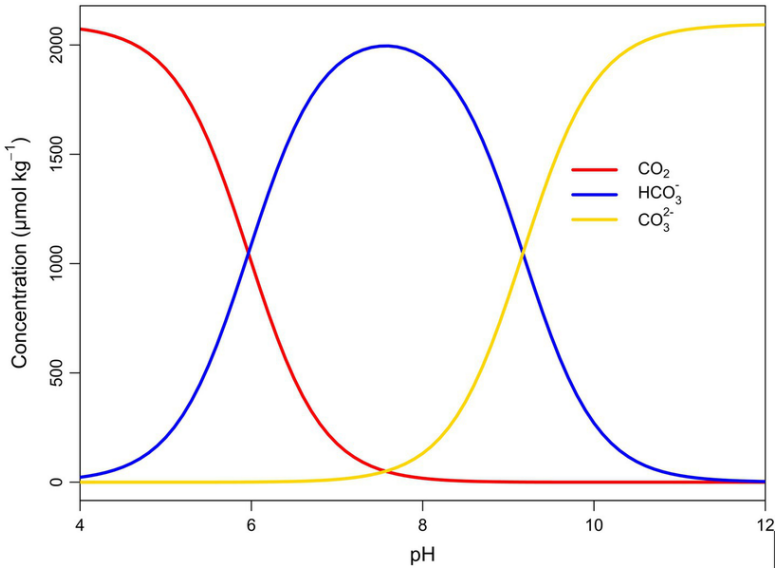


Figure 2.1: The different forms of DIC

2.2 The Biological Carbon Pump

The Biological Carbon Pump (BCP) refers to the collection of biological processes responsible for transferring carbon from the atmosphere and surface ocean toward deeper oceanic layers. Through photosynthesis, phytoplankton converts dissolved carbon dioxide into organic matter according to:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

This organic matter forms the basis of marine food webs. While most of the carbon fixed through photosynthesis is rapidly recycled within the upper ocean, a fraction escapes remineralisation and is exported toward deeper waters as particulate organic carbon (POC). This export represents one of the primary mechanisms through which atmospheric carbon can be sequestered for long periods of time. Besides the production of organic matter, some marine organisms also produce calcium carbonate structures through calcification. This process contributes to a second export pathway known as the carbonate pump.

2.3 The Carbonate Pump and the Rain Ratio

The carbonate pump is driven by a variety of marine calcifying organisms, including coccolithophores, foraminifera and pteropods.

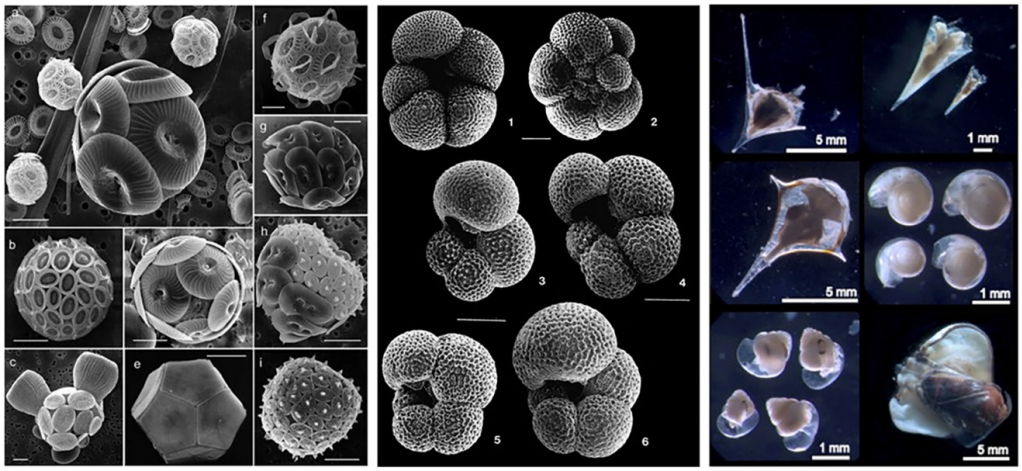


Figure 2.2: Different calcifying organism

These organisms precipitate calcium carbonate and contribute to the formation of particulate inorganic carbon. The relative contributions of organic and inorganic carbon export are frequently quantified through the rain ratio, defined as the ratio between exported particulate inorganic carbon and exported particulate organic carbon. This parameter is particularly important because it influences the efficiency of oceanic carbon sequestration. A high rain ratio generally indicates stronger calcification relative to organic carbon export and may reduce the overall efficiency of the biological carbon pump. Conversely, a lower rain ratio generally favours net carbon storage in the ocean. Because of its importance for climate studies, improving the quantification of the rain ratio is one of the major motivations behind ongoing efforts to develop autonomous PIC measurement technologies.

2.4 Coccolithophores and Marine Calcification

Among marine calcifying organisms, coccolithophores occupy a particularly important place in the ocean carbon cycle. These unicellular phytoplankton are characterized by the production of calcium carbonate plates known as coccoliths, which surround the cell and form a structure referred to as a coccosphere. One of the most widespread species is *Emiliania huxleyi*. Large blooms of this coccolithophore can cover thousands of square kilometres and substantially modify the optical properties of seawater. Such blooms are frequently visible from space because detached coccoliths strongly scatter sunlight. Calcification occurs when calcium ions and carbonate ions combine to form calcium carbonate according to the following reaction:

$$Ca^{2+} + 2HCO_3^- \rightarrow CaCO_3 + CO_2 + H_2O$$

This process directly affects seawater chemistry and contributes to the production of particulate inorganic carbon.

2.5 Optical Properties of Marine Particles

Optical measurements provide a powerful means of studying suspended particles in the ocean. When light interacts with particles, part of the incident radiation is absorbed while another part is scattered in different directions. The magnitude and angular distribution of scattered light depend on particle size, shape, composition and refractive index. Consequently, optical measurements can provide indirect information about particle populations present in seawater. Marine optics has become a major field of research because it allows continuous observations over large spatial and temporal scales. Many autonomous instruments and satellite missions rely on optical principles to estimate biological and biogeochemical variables.

2.6 Scattering and Backscattering

Scattering occurs when light changes direction after interacting with a particle. Part of this scattered radiation is redirected in the forward direction, while another fraction is redirected backwards. The backscattering coefficient is particularly useful because it is closely related to particle concentration and composition. Numerous studies have shown that inorganic particles generally produce stronger backscattering signals than organic particles due to their higher refractive index. Because coccoliths are composed of calcite, they exhibit distinctive optical properties that can be exploited for PIC detection.

2.7 Laser Diffraction and Forward Scattering

Laser diffraction techniques estimate particle size distributions by analysing the angular distribution of scattered light. Larger particles tend to scatter light at smaller angles whereas smaller particles scatter light over a wider angular range. The LISST-200X uses this principle to infer particle size distributions in seawater. Such information is valuable for understanding particle dynamics and interpreting other optical measurements.

2.8 The Operating Principle of the LISST-PIC

Conventional optical instruments generally estimate particle concentration or size by measuring light attenuation, absorption, or scattering. However, these measurements are not specific to calcium carbonate particles and cannot directly distinguish particulate inorganic carbon from other suspended particles. The LISST-PIC was specifically developed to detect particulate inorganic carbon by exploiting a unique optical property of calcium carbonate: birefringence. Birefringence occurs when a material exhibits different refractive indices depending on the polarization direction of the incident light. Calcite, the mineral composing coccoliths, is strongly birefringent and therefore modifies the polarization state of light passing through or scattered by the particle [**?**]. The measurement principle relies on the use of polarized light. A polarized laser beam is emitted through the seawater sample. In the absence of birefringent particles, the polarization state of the transmitted and scattered light remains essentially unchanged. A

second polarizer, oriented perpendicular to the first one, blocks this light and almost no signal reaches the detector. When birefringent particles such as coccoliths are present, the interaction between the polarized light and the calcite crystals modifies the polarization state of part of the scattered light. This depolarized component can pass through the second polarizer and reach the detector. The intensity of the detected signal therefore increases with the concentration of birefringent calcium carbonate particles present in the water [**?**]. Rather than measuring total scattering, the LISST-PIC measures the cross-polarized near-forward scattering signal generated by birefringent particles. This approach allows it to selectively target particulate inorganic carbon while reducing interference from most non-calcifying particles. Because coccolithophores are among the dominant producers of particulate inorganic carbon in the ocean, the measured signal can be used as a proxy for PIC concentration. Laboratory experiments performed by Sun et al. demonstrated a strong relationship between PIC concentration and the cross-polarized scattering coefficient over more than three orders of magnitude, from approximately 0.1 to 400 μg C L^{-1} [**?**]. The results confirmed that the optical response is sufficiently sensitive for oceanographic applications and established the basis for the field validation efforts conducted by the MARSENS laboratory. The LISST-PIC therefore represents one of the first autonomous optical sensors specifically designed to quantify particulate inorganic carbon in situ. By enabling continuous measurements of PIC concentrations, it has the potential to significantly improve the observation of the carbonate pump and the estimation of the rain ratio in marine ecosystems.



Figure 2.3: 3D model of the LISST-PIC

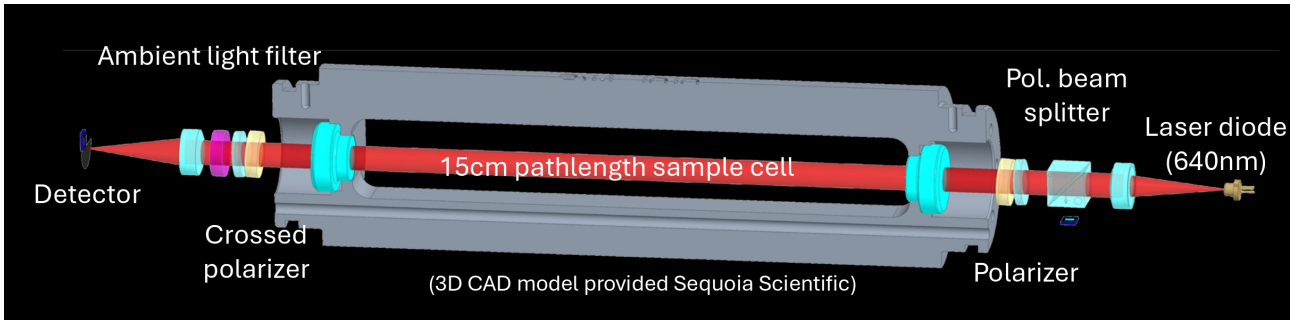


Figure 2.4: The LISST-PIC optical path

2.9 The MARSENS Research Group

The Marine Optics and Remote Sensing (MARSENS) laboratory at Ghent University specializes in the study of marine optical properties and their application to oceanography. The group combines field observations, laboratory experiments, autonomous instrumentation and satellite remote sensing to investigate marine biogeochemical processes. A major focus of the laboratory concerns the development of new technologies capable of improving observations of marine particles and the biological carbon pump. Within this framework, the LISST-PIC project represents one of the group's most innovative developments and forms the scientific background of this internship.

Scientific Objectives and Challenges

3.1 Motivation Behind the Campaign

Although laboratory experiments are essential for the development of new sensors, they cannot fully replicate the complexity of natural marine environments. Particle concentrations, biological activity, hydrodynamic conditions and optical properties vary significantly over time and space, creating conditions that are difficult to reproduce under controlled laboratory settings. For this reason, field validation constitutes a critical step in the development of any oceanographic instrument. Demonstrating the reliability of a sensor under realistic environmental conditions is necessary before considering long-term deployment and scientific exploitation of the measurements. The development of the LISST-PIC sensor follows this same approach. Laboratory experiments successfully demonstrated the ability of the instrument to detect calcium carbonate particles produced by coccolithophores. However, the performance of the instrument in seawater containing complex mixtures of organic and inorganic particles still needed to be evaluated. The acquisition of an extensive field dataset was therefore identified as a key objective for the MARSENS research group.

3.2 The LISST-PIC Validation Effort

One of the major scientific challenges associated with the LISST-PIC concerns the validation of its measurements against independent methods. Traditional PIC measurements rely on water sampling, filtration and laboratory analyses. Although these approaches provide accurate estimates of particulate inorganic carbon concentrations, they are labor-intensive and offer limited spatial and temporal coverage. In contrast, the LISST-PIC is designed to provide continuous autonomous measurements directly in the water column. Demonstrating that optical observations obtained with the LISST-PIC are consistent with established methodologies is therefore essential. This validation process requires the simultaneous acquisition of different types of measurements and the comparison of observations obtained using complementary techniques. In addition to validating the concentration estimates produced by the instrument, the campaign also sought to evaluate its operational reliability under realistic deployment conditions. Particular attention was given to deep deployments reaching 2000 m, which represented an important milestone for the project. The field campaign consequently served both as a scientific experiment and as an engineering validation exercise. The resulting dataset will support future

developments of the instrument and contribute to ongoing research efforts aimed at improving observations of the ocean carbonate pump.

3.3 The Belgica Campaign

To acquire the measurements required for the validation effort, an oceanographic campaign was conducted aboard the research vessel *Belgica*. The campaign lasted approximately twelve days and covered regions of the North Sea and the North Atlantic Ocean. The cruise brought together researchers, engineers and students working on a variety of topics related to marine optics, biogeochemistry and carbon cycling. Because multiple scientific objectives were pursued simultaneously, the campaign relied on a combination of continuous observations, discrete sampling procedures and laboratory analyses. The strategy adopted during the campaign consisted of combining measurements obtained from autonomous optical instruments with water samples collected at selected stations. Such an approach made it possible to compare emerging observation technologies with established analytical methods and thereby evaluate the performance of the different instruments involved. Beyond its role in the LISST-PIC project, the campaign also contributed to several broader research efforts focusing on particle dynamics, marine optics and the biological carbon pump.

3.4 Measurement Systems Used During the Campaign

A large number of complementary instruments were deployed throughout the campaign. Together, these systems provided observations spanning multiple spatial and temporal scales. Rosette casts constituted one of the primary sources of information. The rosette enabled the collection of water samples at selected depths while simultaneously carrying multiple sensors through the water column. The associated measurements provided detailed vertical profiles of optical and environmental properties and represented one of the most important datasets for LISST-PIC validation. Continuous observations were also obtained through the Antilope flow-through platform. This system was connected directly to the ship's underway seawater supply and continuously analysed surface seawater while the vessel was moving. In contrast to station-based observations, which provide information at specific locations, the Antilope generated high-resolution spatial datasets over the entire cruise track. The campaign additionally relied on a DALEC radiometer mounted at the bow of the vessel. By continuously monitoring optical properties throughout the expedition, the instrument provided valuable information for the interpretation of satellite observations and the characterization of environmental conditions encountered during the cruise. Finally, water samples collected during rosette operations were analysed through filtration procedures and laboratory measurements. Incubation experiments were also conducted in order to investigate biological processes under controlled conditions. Together, these activities provided the independent observations required to evaluate the performance of the optical instruments deployed during the campaign.

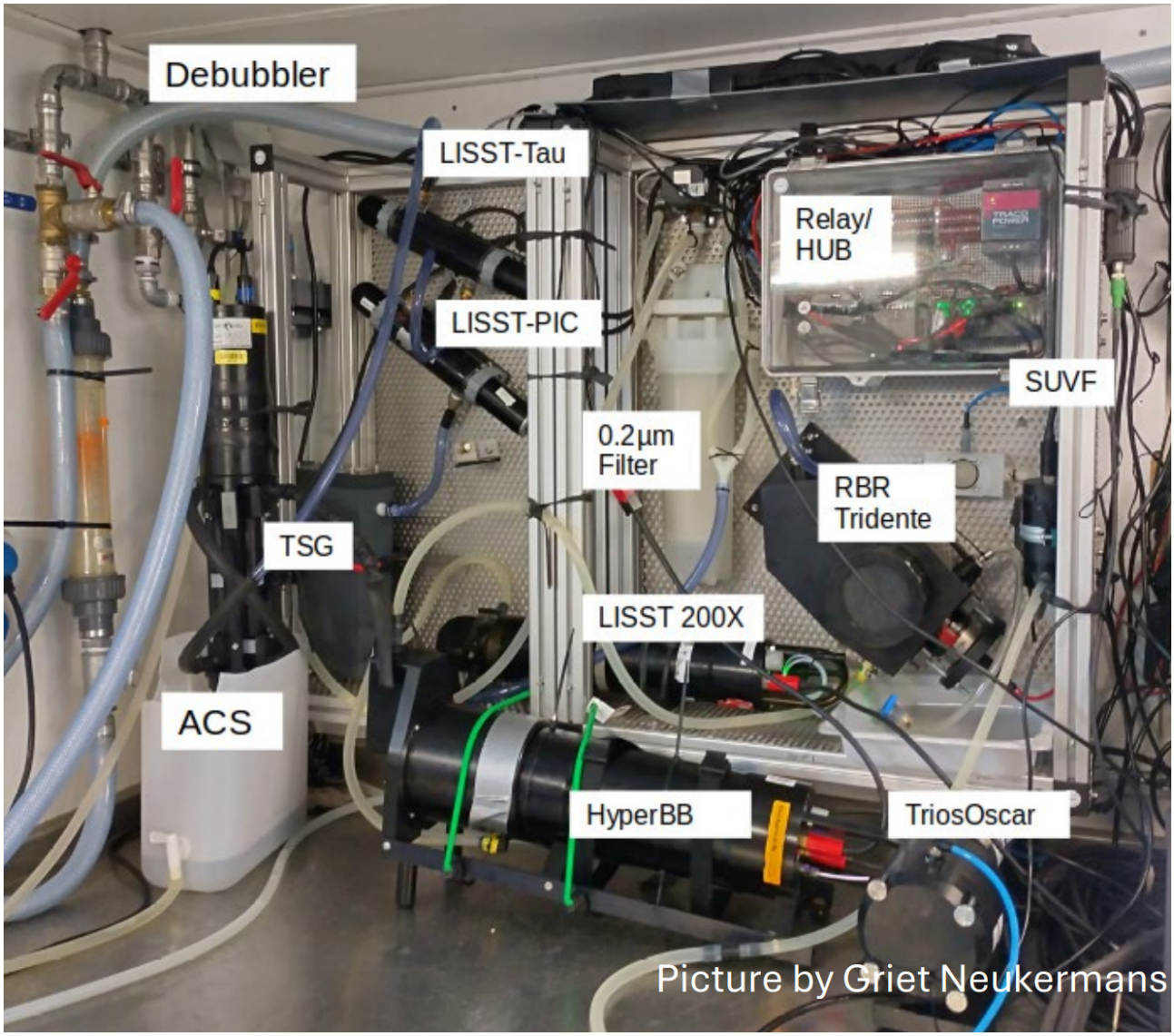


Figure 3.1: The ANTHYLOPE and it's component

3.5 Role of the Internship Within the Project

The internship was conducted within the broader framework of the LISST-PIC validation effort. Rather than focusing on a single isolated task, the work contributed to several aspects of the project, ranging from engineering design and instrumentation testing to field operations and data processing. A particularly important contribution concerned the preparation of a dedicated deployment cage designed to support multiple optical instruments during deep-water operations. This system became one of the key components of the campaign and played a direct role in the acquisition of the observations required for instrument validation. In parallel, the internship provided the opportunity to participate in campaign preparation, data logger

validation, shipboard operations, sample processing and scientific programming activities. Together, these tasks contributed to the success of the campaign while providing exposure to the diverse activities involved in modern oceanographic research.

Internship Activities and Contributions

4.1 Overview of the Internship

The internship took place within the MARSENS laboratory during the preparation and execution of the Belgica campaign. The work performed covered a broad range of activities involving engineering, oceanographic operations and scientific support. Unlike internships centred around a single research topic, this project offered the opportunity to contribute to several ongoing developments within the laboratory. These activities included the design and preparation of scientific instrumentation, testing and validation of acquisition systems, participation in field operations, data processing and literature review. Although diverse in nature, all of these tasks contributed directly or indirectly to the preparation of the campaign and to the broader objective of validating the LISST-PIC instrument under field conditions.

4.2 Design and Development of the Rosette Cage

The design of the deployment cage constituted the most important engineering project carried out during the internship. The objective was to develop a structure capable of supporting three LISST-PIC sensors and one LISST-TAU sensor during deployments reaching depths of 2000 m. From the beginning of the project, the design also had to account for the possible future integration of an RBR Tridente sensor. Because this instrument differs in diameter from the other sensors, additional flexibility had to be incorporated into the design. The cage was intended to be mounted directly on the oceanographic rosette used during the Belgica campaign. One of the main challenges encountered during the design process arose from the limited information available concerning the dimensions and geometry of the rosette itself. The available space appeared restricted, requiring the development of a compact structure while preserving sufficient accessibility for instrument installation, maintenance operations and cable management. I was responsible for the overall mechanical design of the system. This work included the production of the complete three-dimensional CAD model, the selection of the instrument mounting clamps and the design of the interface used to attach the cage to the rosette. Particular attention was devoted to the reliability of the structure because the cage carried expensive scientific instruments that would have been extremely difficult or impossible to recover in the event of a failure during deployment. Several technical challenges complicated the final stages of the project. The structure was not delivered in the marine-grade stainless steel that had initially

been expected. To improve its resistance to seawater exposure, a protective powder coating was applied before deployment. Although this solution reduced corrosion concerns, it introduced a new problem by reducing the effective diameter of many mounting holes. As a consequence, the selected clamps could no longer be installed directly on the structure. With the departure date of the campaign approaching rapidly, the only practical solution consisted of manually enlarging and sanding each affected hole. This work was completed during the week preceding departure and represented one of the most time-critical phases of the project. Further complications originated from the instrument clamps themselves. The delivered components differed from those originally specified during the design phase, creating compatibility issues with the existing design. Multiple exchanges with the supplier were necessary in an attempt to clarify the situation and obtain suitable components. Ultimately, the final configuration relied on two different clamp models supplied by different manufacturers. One clamp design was used on the upper mounting point of each instrument, while a second design was used on the lower support. Despite this compromise, both solutions provided sufficient mechanical retention independently and allowed safe deployment of the sensors. Following assembly and final inspections, the cage was successfully integrated onto the rosette system and deployed during the Belgica campaign. The project provided valuable experience in mechanical design, supplier management, problem solving and scientific instrumentation integration under operational constraints.

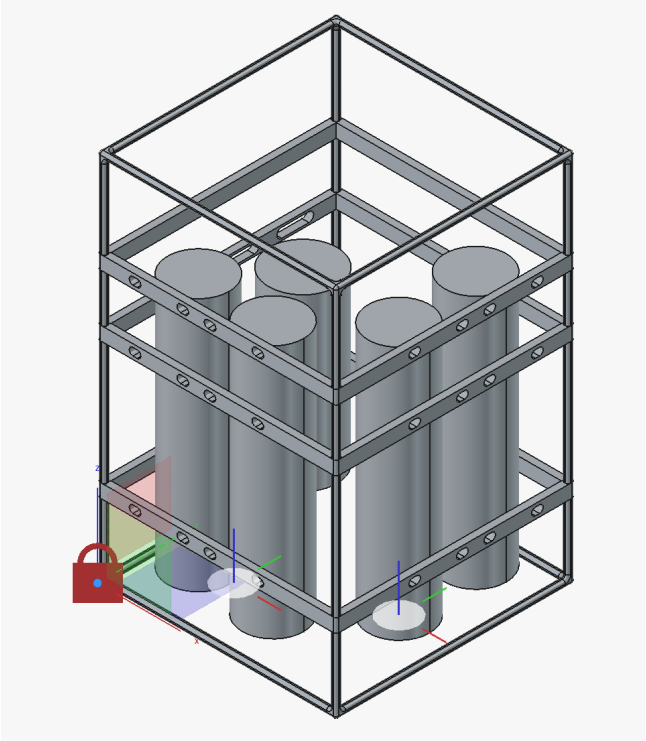


Figure 4.1: 3D model of the cage with the size necessary for each sensor



Figure 4.2: The Cage set up on the Rosette with the sensors and the DL4



Figure 4.3: The Rosette coming out of the water

4.3 Testing and Validation of the Data Logging Systems

Another important aspect of the internship involved the testing and validation of the data acquisition systems used by the laboratory. These systems play a critical role in instrument deployments, as they are responsible for powering the sensors, recording observations and ensuring the integrity of the acquired data. Two generations of data loggers were used within the project. The DL3 corresponded to an existing system capable of operating a limited number

of sensors and supporting shallower deployments. In preparation for the Belgica campaign, a new acquisition system, referred to as the DL4, had been developed to accommodate the four sensors mounted on the rosette cage and to support deployments down to 2000 m depth. The first phase of testing focused on validating the general functionality of both systems. Sensor communication, connector integrity, cable compatibility and data retrieval procedures were systematically verified. These tests were performed to ensure that all instruments could operate simultaneously and that the collected data could be recovered without difficulty after deployment. Once basic functionality had been confirmed, attention was directed towards the electrical behaviour of the system. The power consumption of the different sensors was measured under representative operating conditions in order to estimate the maximum achievable deployment duration. These measurements were particularly important because the autonomy of the acquisition system directly constrained the duration of field operations. To facilitate this analysis, a spreadsheet tool was developed to estimate battery endurance as a function of sensor configuration and operating conditions. This work contributed to operational planning and reduced uncertainties regarding instrument autonomy during the campaign.

capacité batterie (enWh)			DL3 actif(en W)		Lisst-Tau (green then red)(en W)			durée deploiement (en h)	durée deploiement (en jours)
86,58			0,96		0			49,19318	2,049716
			sommeil (en W)		0,26			nombre de prises de mesures par heure :	
			0,00102					60	
			proportion actif par heure :					nombre de mesures par heure :	
			1					3600	
			proportion inactif par heure :						
			0						
intervalle entre les mesures (en minutes)				durée mesures (en minutes)			fréquence		
0				1			1		
délai avant (en ms)		délai après (en ms)		délai total (en min)		durée actif par mesures (en min):			
0		0		0		1			
Notes : environ 60 Ko pour une heure avec un LISST-Tau tt les 15 minutes, soit 0,0004 % du stockage (==> 28 ans de stockage)									
	résistance interne DL3 : 24 ohm (a refaire avec le DL4 pour avoir une autre mesure de la conssomation du PIC								
	Tridente RBR :								
	1 Hz :		8 hz et plus :						
	0,02		0,384						

Figure 4.4: calcul sheet for the DL4 autonomy

4.4 Preparation of the Belgica Campaign

The weeks preceding departure were largely dedicated to campaign preparation. Although often less visible than field activities themselves, this phase is essential for the success of an oceanographic expedition. A significant amount of scientific equipment had to be inspected, assembled, tested and packed before boarding the vessel. Preparation activities included the verification of sensors, cables, connectors and acquisition systems, as well as the organisation of sampling materials and laboratory equipment. Particular attention was devoted to ensuring

that all components required for the validation of the LISST-PIC would be available and operational throughout the cruise. These preparations also highlighted the importance of logistics in oceanographic research. Because replacement equipment is generally unavailable once a vessel has left port, identifying potential issues before departure is critical. The preparation period therefore offered valuable insight into the practical organisation of large scientific campaigns.



Figure 4.5: system to automatize the filtrations on board

4.5 Participation in Field Operations

The Belgica campaign provided extensive exposure to operational oceanography and marine field work. Throughout the cruise, I participated in a broad range of scientific activities associated with data acquisition and sample collection. One of the central components of the campaign involved the deployment of the rosette system. These operations required careful coordination between the scientific team and the vessel crew. Following each deployment, water samples were collected and distributed among the different ongoing experiments and

analyses. In addition to rosette operations, I contributed to filtration activities used to obtain independent measurements of particulate concentrations. These measurements represented an important component of the instrument validation effort, as they provided reference data for comparison with optical observations. The campaign also provided numerous opportunities to assist with troubleshooting and technical support. As is often the case during field work, unforeseen issues occasionally affected scientific equipment. Addressing such problems required close collaboration between scientists, engineers and technicians. This experience offered valuable insight into the practical realities of conducting research at sea and demonstrated the importance of adaptability during field campaigns. Beyond the scientific activities themselves, spending twelve days aboard a research vessel provided a better understanding of how multidisciplinary teams operate in an oceanographic environment. The campaign highlighted the strong interdependence between logistics, engineering and science in the acquisition of high-quality observations.

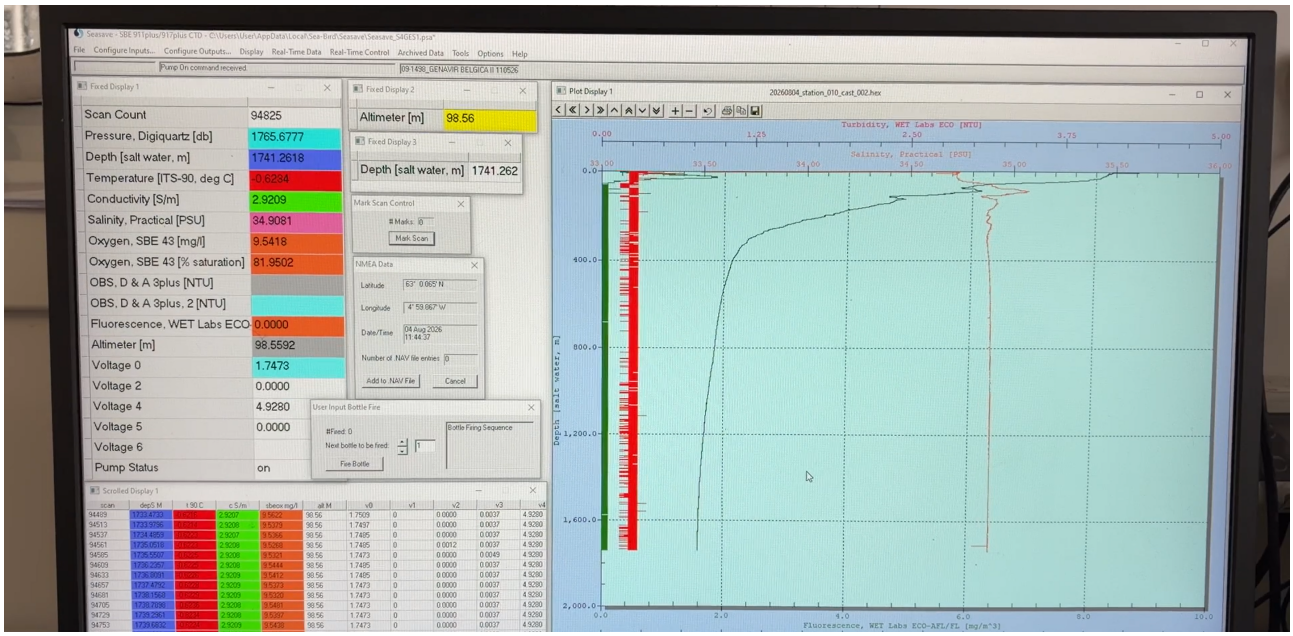


Figure 4.6: the CTD control pannel

4.6 The ANTHYLOPE Flow-Through Platform

Part of the internship was dedicated to activities associated with the ANTHYLOPE flow-through platform. This system continuously analyses surface seawater drawn from the ship's underway seawater supply, allowing measurements to be collected while the vessel is in transit. The platform combines several instruments operating simultaneously, including a LISST-200X, a LISST-PIC, a LISST-TAU, a HyperBB, an ACS, an RBR sensor, a Seapoint UV fluorometer and a SeaBird SBE45 MicroTSG. Together, these instruments provide continuous observations of particle populations and optical properties along the vessel track. Unlike rosette measurements, which provide information at discrete locations, the ANTHYLOPE enables the

acquisition of highly resolved spatial datasets over large distances. Such observations are particularly useful for identifying environmental gradients and investigating the spatial variability of marine particles. During the internship, I contributed to activities related to the preparation and operation of the platform. This work provided a better understanding of flow-through observation systems and their role within modern oceanographic campaigns. The continuous measurements acquired by the ANTHYLOPE also constituted an important complement to both rosette observations and satellite products.



Figure 4.7: The HYPER-BB flow-through chamber

4.7 Data Processing and Scientific Programming

In addition to field activities, the internship included several tasks related to scientific programming and data analysis. These activities provided an introduction to the data processing workflows routinely used within the laboratory. Part of the work focused on the processing of observations acquired with the LISST-200X. Existing Python scripts were studied, modified and adapted in order to facilitate the analysis of particle-size data. This work contributed both to the understanding of the instrument and to the interpretation of the measurements acquired during the campaign. Additional tasks involved the processing of ACS observations. The ACS instrument measures the absorption and attenuation properties of seawater and requires dedicated processing routines before the observations can be interpreted. Familiarisation

with these workflows provided valuable exposure to optical data analysis techniques commonly used in oceanography. Scientific programming activities also included the production of figures and visualisations requested for ongoing projects within the laboratory. Through these tasks, I gained experience in data handling, graphical representation of scientific observations and quality-control procedures applied to oceanographic datasets.

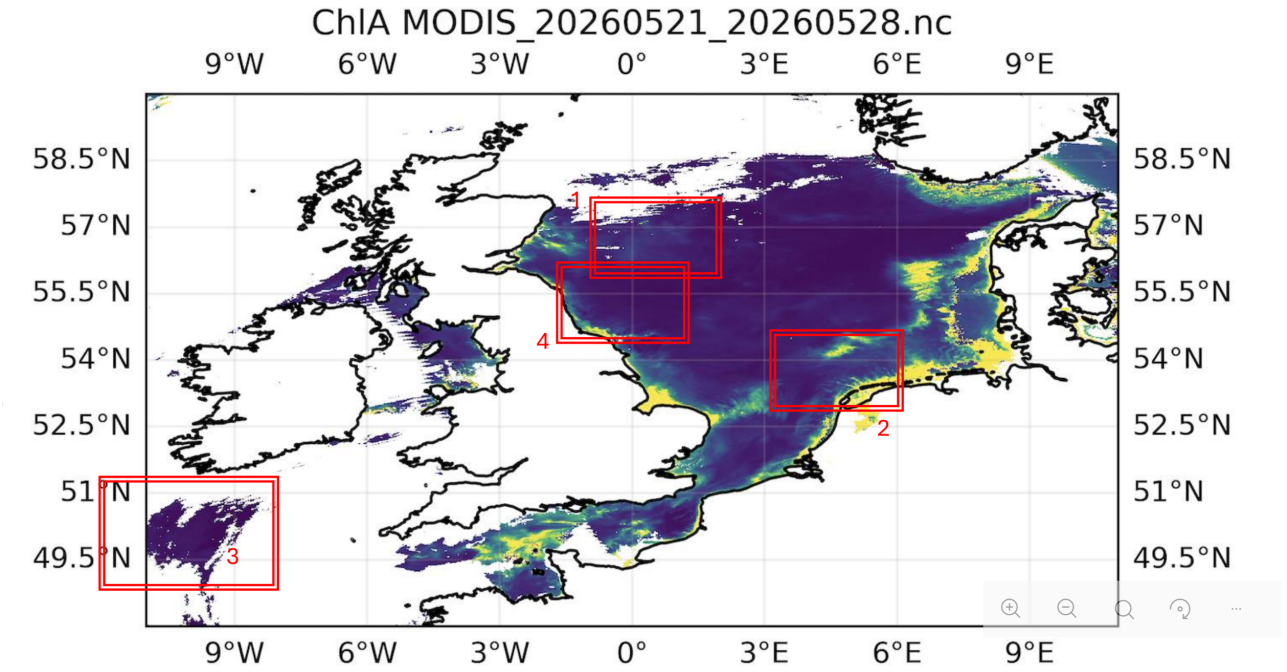


Figure 4.8: Blooms detected in June



Figure 4.9: The stations we took water at on the june cruise

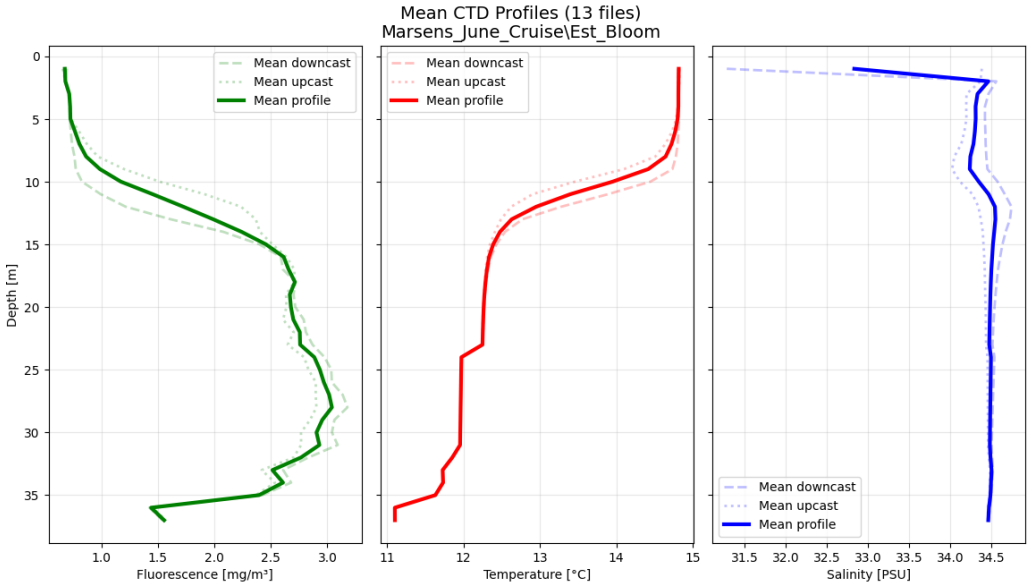


Figure 4.10: Mean values of Fluorescence, temperature and salinity in the Est Bloom

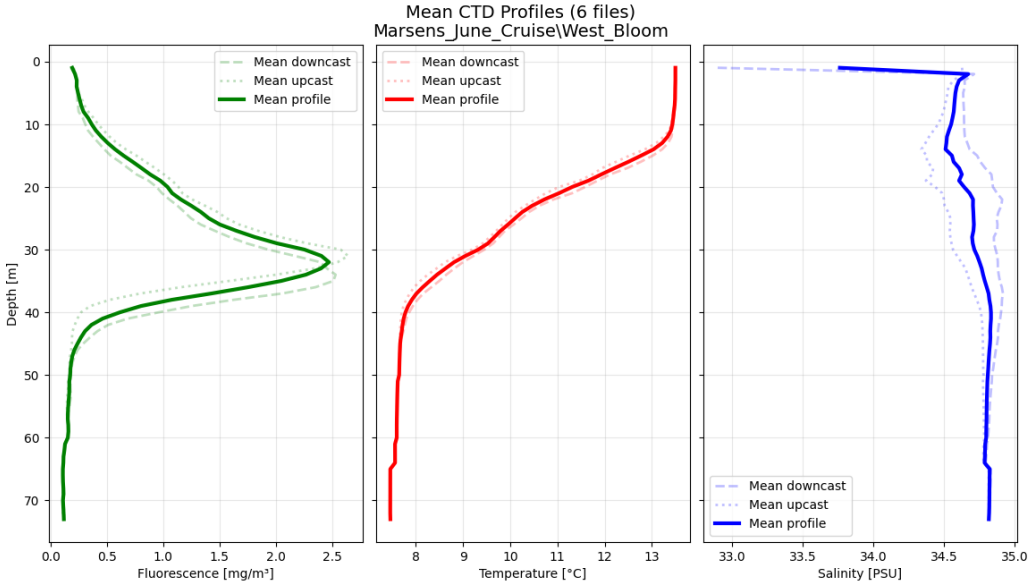


Figure 4.11: Mean values of Fluorescence, temperature and salinity in the West Bloom

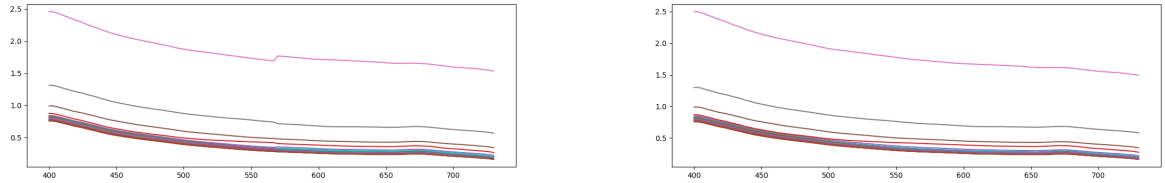


Figure 4.12: ACS data before and after correction.

4.8 Filtration and Sample Processing

Participation in filtration procedures provided direct exposure to one of the most widely used approaches for obtaining measurements of suspended particles in seawater. Although optical instruments can provide continuous observations, filtration remains an essential reference method for the determination of many biogeochemical variables. During the campaign, water samples collected using the rosette were processed according to established laboratory protocols. These procedures contributed to the validation effort by providing independent measurements that could later be compared with optical observations. Beyond the practical aspects of filtration itself, this work offered a better understanding of the relationship between traditional laboratory methods and modern autonomous sensing technologies. Observing the complete chain of operations, from sample collection to processing, provided valuable context for interpreting the data acquired during the campaign.

4.9 Scientific Literature Review

Throughout the internship, time was dedicated to reviewing the scientific literature relevant to the activities of the laboratory. This effort was necessary to acquire the background knowledge required to understand the scientific motivations of the project and the principles underlying the deployed instruments. The literature review covered topics including the marine carbon cycle, coccolithophore biology, calcification processes, ocean optics and optical instrumentation. Particular attention was given to publications related to particulate inorganic carbon observations and the development of the LISST-PIC. This work facilitated a better understanding of the scientific challenges addressed by the MARSENS laboratory and provided the theoretical framework necessary to interpret the observations collected during the campaign.

Ocean Optics XXVII

5.1 Participation in the Conference



Figure 5.1: Opening ceremony of Ocean Optics XXVII.

During the internship, I had the opportunity to participate in Ocean Optics XXVII, one of the leading international conferences dedicated to marine optics, ocean-colour remote sensing and autonomous ocean observations. My participation was made possible through the invitation of my internship supervisor, Griet Neukermans. Beyond attending the scientific sessions, I contributed to the practical organisation of the conference throughout the week. This role provided numerous opportunities to interact directly with scientists, engineers, students and industrial partners working in various areas of ocean observation. The conference covered a broad range of topics including bio-optical modelling, satellite ocean-colour remote sensing, autonomous observing systems, radiative transfer, machine learning applications and optical instrumentation. Several presentations focused on emerging technologies designed to improve observations of the biological carbon pump and marine biogeochemistry, directly echoing the objectives of the LISST-PIC project. Participating in Ocean Optics provided valuable insight into the breadth of ongoing research in marine optics and highlighted the highly collaborative nature of the field. Discussions with researchers from different institutions and countries offered a better understanding of current scientific challenges and possible career paths in ocean science. Beyond the scientific content, this experience reinforced my interest in marine optics and strengthened my motivation to pursue future work in oceanographic research and scientific instrumentation.

Conclusion

This internship provided the opportunity to participate in a wide range of scientific, technical and operational activities within the MARSENS laboratory at Ghent University. Although the work was not centred around a single individual research project, it contributed directly to the preparation and execution of a major oceanographic campaign dedicated in part to the field validation of the LISST-PIC sensor. Among the different tasks performed during the internship, the design and implementation of the rosette cage represented the most significant engineering contribution. The project required addressing multiple technical constraints related to deep-water deployment, mechanical integration, corrosion resistance and supplier management, while operating under tight time constraints prior to the departure of the Belgica campaign. Beyond this engineering work, participation in instrument testing, field operations, filtration procedures and data processing activities provided valuable insight into the full workflow of observational oceanography. These experiences highlighted the close connections between engineering, scientific instrumentation and environmental research. The internship also provided an introduction to marine optics and the study of the ocean carbon cycle. Participation in Ocean Optics XXVII further enriched the internship by providing direct exposure to the international marine optics community. Meeting researchers working on marine optics, ocean-colour remote sensing and autonomous observations broadened my perspective on current scientific challenges and reinforced my interest in this field. Through interactions with researchers, engineers and PhD students, I gained a better understanding of the challenges associated with measuring particulate inorganic carbon and of the broader scientific questions related to marine carbon sequestration. More generally, this experience offered a valuable opportunity to discover the functioning of an international research group and the realities of multidisciplinary scientific projects. It strengthened my interest in oceanography, scientific instrumentation and environmental observation, while allowing me to develop practical engineering skills that will be useful in future academic and professional projects.

Internship Evaluation Form

RAPPORT D'EVALUATION
ASSESSMENT REPORT

Merci de retourner ce rapport par courrier ou par voie électronique en fin du stage à :
At the end of the internship, please return this report via mail or email to:

ENSTA – Bureau des stages - 2 rue François Verny - 29806 BREST cedex 9 – FRANCE
☎ 00.33 (0) 2.98.34.87.70 / stages.brest@ensta.fr

I - ORGANISME / *HOST ORGANISATION*

NOM / *Name Ghent University, Faculty of Sciences, Department of Biology, MarSens research group* _____

Adresse / *Address Krijgslaan 297, 9000 Gent, Belgique* _____
_____

Tél / *Phone (including country and area code) +32474380037* _____

Nom du superviseur / *Name of internship supervisor. Prof. Dr. Griet Neukermans*
_____

Fonction / *Function Professor of Oceanography* _____

Adresse e-mail / *E-mail address griet.neukermans@ugent.be* _____

Nom du stagiaire accueilli / *Name of intern* Louis Habigand

II - EVALUATION / *ASSESSMENT*

Veuillez attribuer une note, en encerclant la lettre appropriée, pour chacune des caractéristiques suivantes. Cette note devra se situer entre **A (très bien)** et **F (très faible)**
*Please attribute a mark from **A (excellent)** to **F (very weak).***

MISSION / *TASK*

❖ La mission de départ a-t-elle été remplie ? A B C D E F
Was the initial contract carried out to your satisfaction? (LISST-200X data processing task was skipped)

❖ Manquait-il au stagiaire des connaissances ? ☐ oui/*yes* ☒ non/*no*
Was the intern lacking skills?

Si oui, lesquelles ? / *If so, which skills?* _____

ESPRIT D'EQUIPE / *TEAM SPIRIT*

❖ Le stagiaire s'est-il bien intégré dans l'organisme d'accueil (disponible, sérieux, s'est adapté au travail en groupe) / *Did the intern easily integrate the host organisation? (flexible, conscientious, adapted to team work)*
A B C D E F

Souhaitez-vous nous faire part d'observations ou suggestions ? / *If you wish to comment or make a suggestion, please do so here. It was a pleasure to have Louis in the MarSens team; he is a true team*

player; always ready to support activities where he could, he got along very well with everyone in the team, and was really well appreciated by all.

COMPORTEMENT AU TRAVAIL / *BEHAVIOUR TOWARDS WORK*

Le comportement du stagiaire était-il conforme à vos attentes (Ponctuel, ordonné, respectueux, soucieux de participer et d'acquérir de nouvelles connaissances) ?
Did the intern live up to expectations? (Punctual, methodical, responsive to management instructions, attentive to quality, concerned with acquiring new skills)?

A B C D E F

Souhaitez-vous nous faire part d'observations ou suggestions ? / *If you wish to comment or make a suggestion, please do so here* Yes, Louis was punctual - the very few occasions that he would be late, he communicated it clearly, without any issue. Louis also made every effort to ensure maximum quality of this work and was very eager to learn new things and ready for action.

INITIATIVE – AUTONOMIE / *INITIATIVE – AUTONOMY*

Le stagiaire s'est –il rapidement adapté à de nouvelles situations ? A B C D E F
(Proposition de solutions aux problèmes rencontrés, autonomie dans le travail, etc.)

Did the intern adapt well to new situations? A B C D E F
(eg. suggested solutions to problems encountered, demonstrated autonomy in his/her job, etc.)

Souhaitez-vous nous faire part d'observations ou suggestions ? / *If you wish to comment or make a suggestion, please do so here Louis worked autonomously where he felt confident and asked for help if needed. Louis pocesses impressive work ethics and works as long and as hard as needed to finish a task assigned to him.*

CULTUREL – COMMUNICATION / *CULTURAL – COMMUNICATION*

Le stagiaire était-il ouvert, d'une manière générale, à la communication ? A B C D E F
Was the intern open to listening and expressing himself /herself?

Souhaitez-vous nous faire part d'observations ou suggestions ? / *If you wish to comment or make a suggestion, please do so here Louis is a gentle soul, with the heart in the right place; always ready to help where he could and clearly communicating his readiness to assist. His communication in French as well as English was very clear and effective.*

OPINION GLOBALE / *OVERALL ASSESSMENT*

❖ La valeur technique du stagiaire était : A B C D E F
Please evaluate the technical skills of the intern:

III - PARTENARIAT FUTUR / *FUTURE PARTNERSHIP*

❖ Etes-vous prêt à accueillir un autre stagiaire l'an prochain ?

Would you be willing to host another intern next year? ☒ oui/*yes* ☐ non/*no*

Fait à Gand _____, le 20/10/2026 _____
In _____, on _____

Signature Entreprise _____ Signature stagiaire
Company stamp _____ *Intern's signature*



Merci pour votre coopération
We thank you very much for your cooperation

Bibliography

[1] J. André, “Petites leçons de typographie,” *IRISA*, 1990.