KADI

Report detailing training achievements and lessons for implementation of coastal observing systems elsewhere in southern Africa

Deliverable 4.5. HORIZON-INFRA-2021-DEV-01-02

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kadi-project.eu

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LIST OF AUTHORS

NAME	INSTITUTION
Thomas G. Bornman	NRF/SAEON
Abdirahman Omar	NORCE
Richard Sanders	NORCE
Louisa Giannoudi	HCMR
Matthew Saunders	TCD

Executive Summary

The ocean plays a key role in the Global Carbon Cycle, taking up about 25% of the CO_2 we release to the atmosphere via fossil fuel combustion, cement manufacture and changing patterns of land usage. The size and future evolution of this transfer will regulate the future development of climate, and the costs associated with managing this, leading to a need to measure it precisely. However, this net uptake is the difference between two much larger transfers across the air-sea interface which vary substantially in space and time, with coastal processes playing a significant role in the net flux. The observing network is currently configured as a loose affiliation of continental and national scale networks which vary in strength. Observing systems should be established and implemented into a set of systems that could form a global one, having also an international cooperation with uniform data handling and data archiving. Despite the high level training of staff needed, it is possible to be achieved through building human capacity and already well established RIs. This report describes two activities which KADI supported in the ocean training sphere. The first was a workshop in Ostend, Belgium from 6 to 9 October 2023 in VLIZ (the Flanders Marine Institute) focussed on surface ocean pCO_2 observations, which aimed at both training African Scientists in key parts of the so-called value chain that links observations to policy and integrating African observations and perspectives into a future vision for a global ocean CO_2 observing system as one key component of EU – Arica knowledge exchange. Together these allowed two strategic aims of KADI to be achieved: 1) the design of a global RI style observing system including a strong African component and 2) the investment in human capacity needed to run such a system. The first event was supported by the Global Carbon Project, the surface ocean CO_2 Atlas (SOCAT), the International Ocean Carbon Coordination project (IOCCP), the US National Ocean and Atmosphere Agency (NOAA), VLIZ and the EU project GEORGE lead by ICOS RI which focuses on ocean carbon technology development and innovation). It was divided into three parts: 1) working on the process by which sparse pCO_2 observations are converted into estimates of global ocean CO_2 uptake, 2) linking the international observing community together to develop a vision for the future structure of a global observing system known as SOCONET (the Surface Ocean CO2 Network) and 3) training users in the quality control procedures used in the large international databases that support our understanding of the oceans role in the global C cycle. KADI supported the attendance of six African Scientists from a variety of career stages across the continent. This both enhanced the African capacity to quality control observations and to enter them into global databases (and thus use the data) and ensured that African voices were heard in the main conference outcome, the so called the concept of the Ostend declaration, a multinational (Declaration_on_Operationalising_the_Surface_Ocean_Carbon_Value_Chain.pdf) statement around the commitment of scientists to quantifying the ocean carbon sink and a clear statement around the scientific expectations around the role of funding agencies. The second event was a training course in coastal greenhouse gas measurements held in the Algoa Bay marine environment at the Nelson Mandela University, Gqeberha, South Africa. This focussed on practical hands-on training and resulted in a cohort of African students being upskilled to deliver the key elements of SOCONET as detailed in the Ostend Declaration. The course participants were trained on blue carbon measurements in a tidal estuary, coastal biogeochemistry measurements, analyses of sediment and seawater samples in the laboratory, and analyses and interpretation of the measured results. Also, discussions were held to explore and elucidate the current needs, resources and limitation for building a community of operators, funders and end-users of ocean carbon cycle science in Africa. This resulted in a list of insights for the implementation of coastal observing systems in Africa. Also, regional stakeholder champions were identified for collaboration in future training events.

KADI

List of abbreviations

Abbreviation	Definition
AfriCON	African Carbon Observation Network
CH4	Methane
CO_2	Carbon Dioxide
COVID-19	Corona virus disease
CRM	Certified Reference Material
CSIR	Council for Scientific and Industrial Research
CTD	Conductivity, Temperature and Depth instrument
DIC	Dissolved Inorganic Carbon
ERDDAP	Environmental Research Division's Data Access Program
ERIC	European Research Infrastructure Consortium
EU	European Union
G3W	Global Greenhouse Gas Watch
GC	Gas Chromatography
GCB	Global Carbon Budget
GEORGE	Next Generation Multiplatform Ocean Observing Technologies for Research Infrastructures
GHG	Greenhouse Gas
GOA ON	Global Ocean Acidification Observing Network
GOOS	Global Ocean Observing System
ICOS	Integrated Carbon Observation System
IOCCP	International Ocean Carbon Coordination Project
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
KADI	Knowledge and climate services from an African observation and Data research Infrastructure
KMFRI	Kenya Marine and Fisheries Research Institute
N2O	Nitrous oxide
NOAA	National Oceanic and Atmospheric Administration
OTC	Ocean Thematic Centre
pCO_2	Partial pressure for CO_2

POC	Particulate Organic Carbon
RI	Research Infrastucture
RSET	Rod Set Elevation Table
SAEON	South African Environmental Observation Network
SAMI	Submersible Autonomous Moored Instrument
SOCAT	The Surface Ocean CO_2 Atlas
SOP	Standard Operating Procedure
TOC	Total Organic Carbon
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
VLIZ	the Flanders Marine Institute
WMO	World Meteorological Organization

1. Introduction

The KADI (Knowledge and climate services from an African observation and Data research Infrastructure) project aims to provide concepts for developing the best available science and science-based services in Africa. The project includes several pilot studies (in WP2) designed to deepen and test this general concept by providing experience to co-design the requirements of climate services (WP1) with observational design and technical feasibility. The Ocean biogeochemistry pilot (WP2 Pilot 2) was conducted at monitoring sites run by SAEON in the Algoa Bay, South Africa to quantify key elements of the coastal carbon cycle relevant to usage of the ocean and the role that coastal ocean plays in regulating global climate.

This document reports on two training events designed and delivered by Pilot 2 and as part of the KADI Knowledge exchange platform (WP4) with the objectives of (i) contributing towards building the community of operators, funders and end users in ocean carbon cycle science in southern Africa, (ii) building critical mass in key skills required to deliver a RI style science operation in S. Africa including links to end users, fundraising and practical skills, and (iii) training staff engaged in operating long term carbon observing systems.

Section 2 reports on the first event which was a workshop in Ostend, Belgium from 6 to 9 October 2023 in VLIZ (the Flanders Marine Institute) focussed on surface ocean *p*CO_2 observations. The event aimed at both training African Scientists in key parts of the so-called value chain and integrating African observations and perspectives into a future vision for a global ocean CO_2 observing system. Originally, the WP4 training events were planned to be hosted at the pilot sites in S. Africa. However, the KADI project team identified the Ostend workshop as a golden opportunity for training on international standards and as a platform to avail of wider opportunities to enhance EU-African knowledge exchange. Therefore, it was decided to support participation of African Scientists from a variety of career stages.

Figure 1: Map showing countries that attended the two training events.

Section 3 reports on the second event which was a training course in coastal greenhouse gas measurements held in the Algoa Bay marine environment at the Nelson Mandela University, Gqeberha, South Africa. This focussed on practical hands-on training and resulted in a cohort of African students being upskilled to deliver the key elements of SOCONET as detailed in the Ostend Declaration.

Section 4 summarises the insights gained (lessons learnt) for implementation of coastal observing systems in Africa, based on the discussion engaged during the training events. This section also provides an overview of further aspects to consider when designing new training events aiming at building capacity in coastal observing systems in Africa.

2. Surface pCO_2 workshop, Ostend, Belgium, October 2023

2.1 Workshop description and content

The first event supported under this activity was the participation of six African carbon cycle scientists (from Benin, Egypt, Ghana, Mozambique, Nigeria, South Africa) in a workshop focussed on the Surface Ocean CO_2 sink in Ostend, Belgium in 6 to 9 October 2023.

The workshop was facilitated by multiple organisations and EU projects (Workshops on surface ocean pCO_2 observations | OTC Carbon Portal) and gathered more than 100 ocean experts and stakeholders representing Europe, Australia, Asia, North America, South America and Africa. The objectives of the workshop were (i) to assess the status of the multi-component community effort capable of measuring, storing, synthesising and mapping of the surface ocean carbon information, and (ii) to call for concerted international and intergovernmental efforts to create a robust, resilient and sustainable surface ocean carbon observing system.

Figure 2. Attendees at the 2023 Ostend Workshop.

The workshop consisted of three sessions focusing on 1) Data-based air-sea CO_2 fluxes and uncertainty, 2) SOCONET design and pCO_2 products and 3) SOCAT strategy and quality control. It represented the first opportunity for the surface ocean pCO_2 community to come together en masse since the COVID-19 pandemic and was motivated by a widespread recognition that the status of the value chain linking observations through to policy advice is too weak and required strengthening. This is clear based on the persistent reports within the Global Carbon Project that the quantity of pCO_2 data was declining and the requests for assistance in compiling the annual SOCAT release as well as a statement that the system was under pressure (Fig. 3).

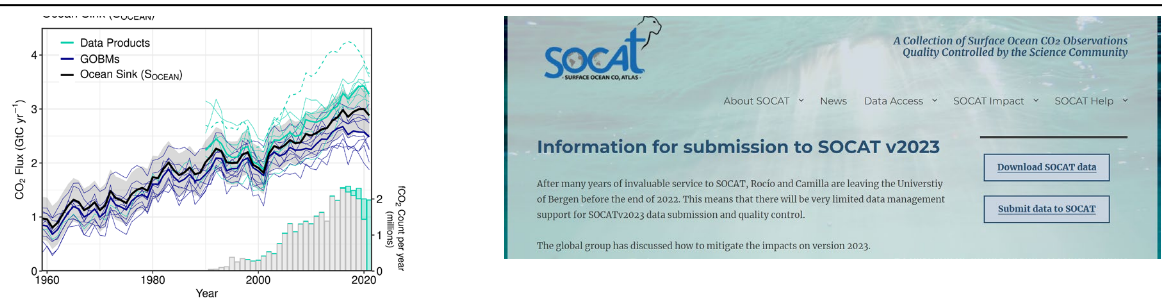
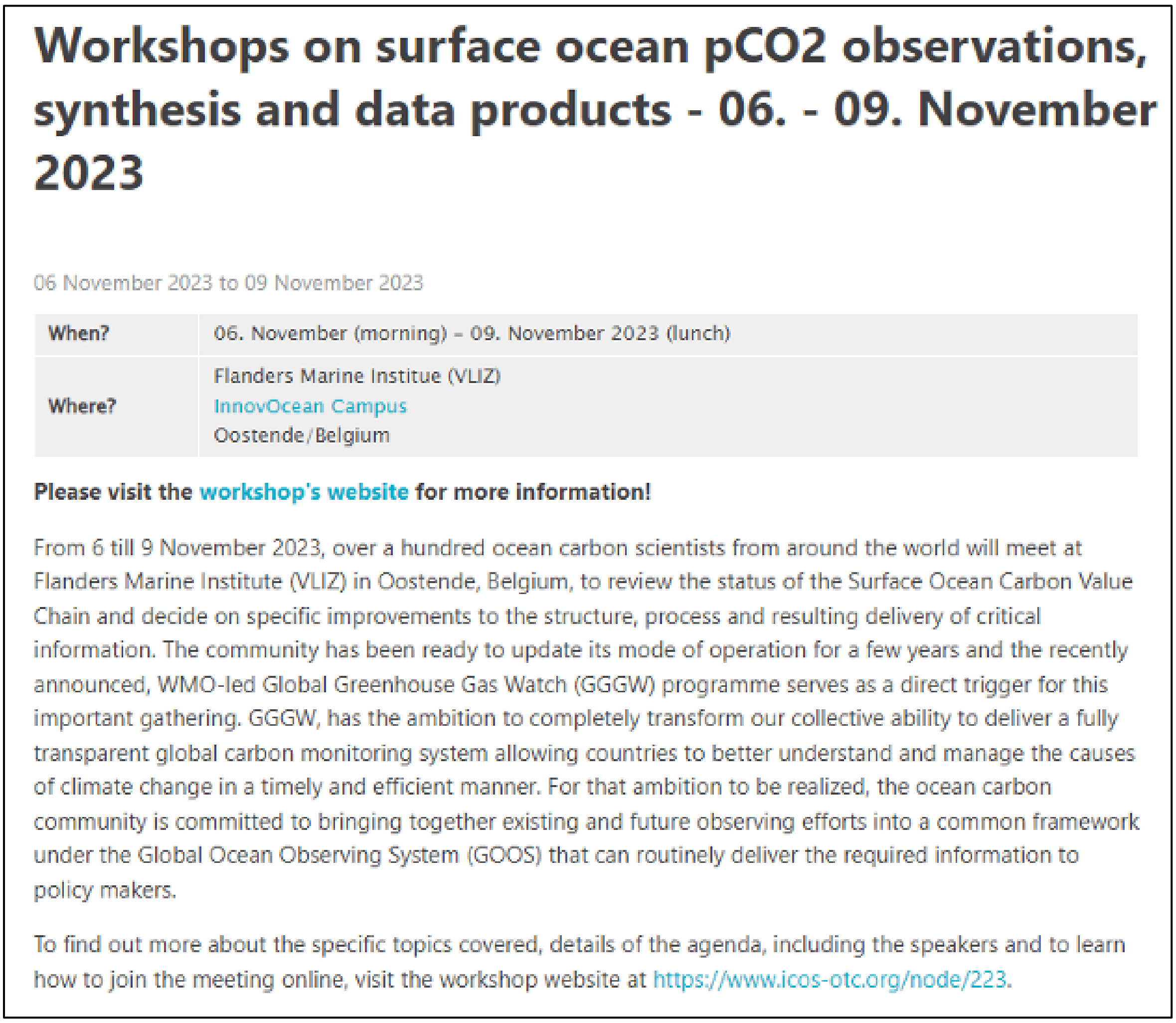


Figure 3. Time series of submissions to the SOCAT database (left) and statement around 2023 SOCAT submissions showing urgency of taking action to enhance the SOCAT system (right).

2.2 KADI supported participants

In mid 2023, the executive board of KADI project decided to support the involvement of African scientists in the workshop, and this training opportunity was widely advertised through key research networks such as https://africanscientists.africa/ and the website of the ICOS Ocean thematic Centre (Figure, 4), and personal contacts. Applications were shortlisted by a panel and the selected candidates were informed that they would receive financial support to cover the costs associated with flights, accommodation and subsistence while any other costs would be covered by their home institution. Also, the candidates were asked to write a short report after their participation and, if possible, to have some social media activity to disseminate this knowledge exchange event within their networks during the workshop.



Workshops on surface ocean pCO2 observations, synthesis and data products - 06. - 09. November 2023

06 November 2023 to 09 November 2023

When?	06. November (morning) – 09. November 2023 (lunch)
Where?	Flanders Marine Institue (VLIZ) InnovOcean Campus Oostende/Belgium

Please visit the workshop's website for more information!

From 6 till 9 November 2023, over a hundred ocean carbon scientists from around the world will meet at Flanders Marine Institute (VLIZ) in Oostende, Belgium, to review the status of the Surface Ocean Carbon Value Chain and decide on specific improvements to the structure, process and resulting delivery of critical information. The community has been ready to update its mode of operation for a few years and the recently announced, WMO-led Global Greenhouse Gas Watch (GGGW) programme serves as a direct trigger for this important gathering. GGGW, has the ambition to completely transform our collective ability to deliver a fully transparent global carbon monitoring system allowing countries to better understand and manage the causes of climate change in a timely and efficient manner. For that ambition to be realized, the ocean carbon community is committed to bringing together existing and future observing efforts into a common framework under the Global Ocean Observing System (GOOS) that can routinely deliver the required information to policy makers.

To find out more about the specific topics covered, details of the agenda, including the speakers and to learn how to join the meeting online, visit the workshop website at https://www.icos-otc.org/node/223.

Figure 4. Screenshot of announcement for people to join the workshop.

2.3 Key outcomes

The most important outcome from the workshop was a declaration on the operationalisation of the value chain of the observing network SOCONET (the Surface Ocean CO_2 Observing Network) which is developed by a community of experts and stakeholders. The full declaration can be downloaded here. It first introduced the societal challenge of climate change and its primary cause, namely, the accumulation of CO_2 (the main GHG) in the atmosphere and that, through the Paris agreement, 196 parties agreed on the need to peak and reduce GHG emissions, to reach net zero by 2050. Furthermore, it identified the need to routinely monitor the ocean carbon uptake as essential for understanding the global impacts of climate change and its future projections in support of climate policy making. Finally, the declaration has drawn attention to the fact that the SOCONET, despite its success in delivering critical information, lacks formal integration into the organizations mandated by the United Nations Framework Convention on Climate Change (UNFCCC). Several recommendations were presented in the declaration on how to improve the current situation. The globally representative nature of the authors list and participants at the workshop lead to the influence that the declaration had: it was the key document that supported the application made to GOOS for SOCONET to become a recognized network. The advantage of this, is that all observing systems globally now have a 'home' which can unlock funding and further support, particularly within the G3W which has a strong capacity building element.

The African participants reported that the workshop was highly useful both at technical and institutional levels. They gained essential knowledge about the protocols, methods, and standards required to conduct ocean carbon and ocean acidification research. They also gained the valuable insight that observing systems are often implemented with regional inputs and their home institutions can make important data contributions. At the completion of the workshop, the participants looked forward to (i) engaging in collaborative efforts, such as co-authoring research papers, with the scientists they connected with during the workshop, (ii) look for opportunities to partake in relevant regional cruises, (iii) attend workshops and conferences to showcase their regional studies and research, (iv) advocate the involvement of their home institutions in international research activities focusing on oceanic greenhouse gas observations such as the SOCONET.

Below are a few quotes from the report prepared by one of the African participants.

> **" Participating in the workshop was a perfect fit for my research and professional development as both a Doctoral Candidate and Research Scientist."**

*"*In conclusion, the workshop provided a valuable platform for ocean carbon scientists to address the requirements of the G3W initiative and discuss advancements in the Surface Ocean Carbon Value Chain. The discussions and outcomes of the workshop will have a significant impact on the improvement of the uncertainties associated with the Global Carbon Budget (GCB) and facilitating the routine provision of crucial information to policymakers. Moreover, the workshop fostered international collaboration and facilitated the sharing of knowledge among experts in the field.*"*

Supporting African researchers' participation in international technical workshops, like the Ostend workshop, is a good way to build capacity in potential contributors of African observation network while fostering global network for observational data to advance fundamental knowledge, improve forecasts, and provide longer-term projections of climate, weather, and ocean ecosystems.

3. Coastal Greenhouse Gas Training Course, Ocean Sciences Campus, Nelson Mandela University, Gqeberha, South Africa, 12-15 March 2024.

3.1 Course content and objective

The main objective of the course was to support the establishment of an African network of Greenhouse Gas (GHG) measurements by giving early career scientists/professionals an overview of available sensors, hands-on training, fieldwork, data collection, data analysis, data processing (e.g. using CO_2SYS https://www.ncei.noaa.gov/access/ocean-carbon-acidification-data-system/oceans/CO2SYS/co2rprt.html#aboutco2sys) and management, and international networking.

Specifically, the participants learnt about how coastal carbon observations can be made with sufficient funding and what can be done with limited resources. The course incorporated three components as briefly described.

1. Lectures: topics covered broad coastal biogeochemistry with a focus on some specific aspects such as the ICOS marine stations, blue carbon (estuaries and salt marshes), coastal oceans, and the open ocean.
2. Field work and measurements: students were divided into two groups which alternated between the following activities: A) Blue carbon measurements in a tidal estuary, including the use of a GHG analyser and the collection of water and sediment samples, B) Coastal biogeochemistry off a small research vessel to collect marine samples (using the GOA-ON in a box kit [https://www.goa-on.org/resources/kits.php)](https://www.goa-on.org/resources/kits.php) and deploy/recover pCO_2 and pH instrumentation, and C) analyses of the sediment and water samples in the Carbon Laboratory.
3. Data analyses: training on the analyses and interpretation of the results was followed by the two groups writing their reports and presenting their results.

Figure 5. Group photograph showing course participants and presenters/trainers in Gqeberha.

3.2 Course participants

On 3 October 2023, the course was advertised, and an online application form was provided via the project website (Figure 6), through contacts of the KADI partners and via ICOS social media.

15 participants from the African continent were invited to join a four-day training course on coastal oceanographic and carbon data collection, analysis and sharing. Priority was given to candidates with a background in marine science or equivalent who are committed to use the acquired competency at their home institutions. Furthermore, gender composition was given a weight in the selection processes. The timeline of the process from application to final invitation of participants was also included (Fig. 6).

As part of the KADI project, we invite 15 participants from the African continent to join a four-day training course on coastal oceanographic and carbon data collection, analysis and sharing.

The course will take place in Gqeberha, South Africa 12-15 March 2024.
The course will encompass sensor overview, hands-on training, fieldwork, data collection, data analysis and management, and international networking. The participants might be students, technicians, or early career researchers affiliated to educational/research/ governmental institutions working or studying in this field, and thus, it is required that participant have some basic knowledge about oceanography, greenhouse gas/carbon observations and marine systems. Good English language proficiency is required.

The training programme will be delivered by local and international researchers with extensive expertise in the relevant fields.
We will cover your international travel expenses, accommodation, and food during the course. Successful participants will be expected to write a summary report at the end of the training course outlining the benefit of the programme to their work/study.

To apply for a place on this course, please complete the application form below. **Deadline for application 1st of November 2023**.

Priority will be given to candidates with a background in marine science or equivalent who are committed to use the acquired competency at their home institutions. In the selection process we aim for a balanced gender composition.

Each candidate will be responsible for obtaining visa to South Africa – if relevant.

The timeline of the process will be as follows:

- Submission of application – 1 November 2023
- Selection of candidates – 15 November 2023
- Reply to all applicants about the selection – 17 November 2023
- Confirmation by candidates – 1 December 2023
- Invitation letters to selected candidates – 5 December 2023
- Training course – 12-15 March 2024

Figure 6. Screenshot of advertisement placed on ICOS website.

Twenty-five applications were received before the deadline. A panel of four KADI scientists reviewed the applications, and thirteen (four female and nine male) applicants fulfilled the advertised requirements and provided the additional information requested (e.g., passport number, permission from manager, etc.) and they were sent an official invitation letter. The names and affiliations of the participants and the trainers/presenters that took part in the workshop are provided in Appendices 3A and 3B, respectively. The attendance register is provided in Appendix 3C.

3.3 Summary of activities

Day 1: Each participant presented 3 slides on their expertise and capacity in their country. This was followed by a needs analysis for the region.

Day 2: The group was split in two and took turns to attend both field trips, i.e. 1) Blue carbon and Greenhouse Gas analyses in estuaries and 2) oceanography, biogeochemistry and deployment of ocean acidification mooring. During the afternoon the group was split into three groups and trained on laboratory techniques, i.e. soil carbon analyses, water biogeochemistry and TOC/POC analyses.

Plate 1. Dr Omar presenting the opening lecture


Plate 2. Participants visiting the Zooplankton laboratory


Plate 3. Sediment coring in the Swartkops Estuary

Day 3: Presentations by experts on the Global Carbon Cycle, blue carbon in estuaries, GHG measurements in the coastal environment, rod surface elevation tables (RSETs) to determine sediment elevation, and GOA-ON (ocean acidification). Laboratory analyses was continued after tea in the afternoon followed by a short field trip to see stromatolites along the coast.


Plate 4. pH mooring being prepared for deployment

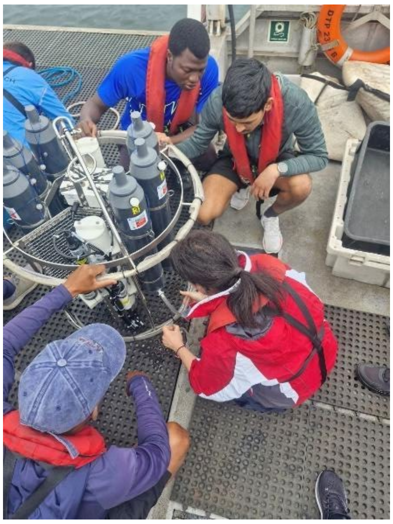


Plate 5. Training on collecting carbon and pH samples from the CTD/Niskin

Plate 6. All the participants on the R/V Observer

Day 4: Data from a mooring deployed on Day 2 was presented to the trainees and they were showed how to analyse and interpret the data. A presentation was also given on ERDDAP and the free use of the data server for data management. Trainees started working on their data analyses and workshop reports. The afternoon was dedicated to a discussion to design a sustainable and operational observation network for Africa.

A detailed programme of the workshop is provided in Appendix 2.3.

3.4 Discussions on the potential future structure of an African Observing Network:

During this workshop, a significant amount of time was spent on discussions to elucidate the current needs, resources and limitation for building a community of operators, funders and end-users in ocean carbon cycle science in Africa. These discussions are summarised below.

3.4.1 Regional needs

A discussion on regional needs to establish a basic African network of coastal biogeochemistry sites resulted in the following key statements:

- A list needs to be drawn up of what equipment, resources and capacity is available in each of the countries.
- It will be important to harmonise methodology (SOP & Ocean Best Practises manuals) between the different countries in Africa. To this end, the workshop identified the following:
    - Establish a Task Team for Ocean Best Practises in coastal carbon observations in under-resourced countries
    - Link this task team to best practices for real-time moorings
    - Link this task team to the Task Team for Ocean Best Practices in coastal Observations in under resourced countries (already established)
- Establish calibration centres, either in Africa or in the Mediterranean region that will be easily accessible for the calibration of *in situ* sensors
- Conduct inter-laboratory comparisons
    - CRMs being developed in other countries (for easier access). CRM development in Europe is still under discussion.
- Biggest need is for basic carbon analyses instruments, especially for those countries with no national funding available. Some suggestions provided during the workshop include:
    - Apply for small grants to some of the agencies. Important to show that there is capacity (and ambition) before applying for a grant.
    - Countries can also ask for partial assistance, e.g. some equipment needed to conduct observations or to fund analyses of samples in other countries.
    - Dedicated large grant for Africa on this topic would be ideal, i.e. EU-Horizon type funding or similar.
- Specialist training on the use of equipment, analyses of samples and data was also highlighted as critical. To this end, the proposed network should consider:
    - Mentorship programmes within Africa and with other international experts/entities. This could be managed by a community if practice in Africa.
- Collaboration between countries and more developed countries (e.g. project grants, mobility grants, exchange programmes, etc.) will be very important in the establishment of an African network.

3.4.2 Designing an African Carbon Observation network

To design an African network, the following should be considered:

- An initial high-level approach is required to ensure buy-in from countries into the establishment of an African Carbon Observation network.
- Establishment of regional hubs across Africa with capacity and expertise to analyses samples and produce guidance and advice will be required
    - Regional hubs can test and calibrate lower-cost sensors.

- Funding: External funding will be easier to obtain than National funding in most of Africa
    - Rotation of key equipment is also an option, but this will need regional hubs, community of practice, or countries that are near each other.
    - Important to start small with small grants and build capacity, thereafter it will become easier to apply for larger grants and grow the collaboration.
    - Show proof of concept first and use that as a platform to apply for funding and collaboration
- Conducting the mapping exercise on the capability of countries and availability of equipment will be critical to start the process.
- A Pan-African network should consider the following:
    - Link marine and terrestrial hotspots, i.e. catchment to the coast
    - Consider sustainability, i.e. what other activities are being conducted (and links to terrestrial) in the area
    - Identify existing research and research Infrastructure activities that carbon/GHG observations can be combined with to save on effort and use existing long-term datasets.
    - Align activities with government priorities
    - Connect data being collected for other research initiatives (IPCC, IPBES, etc.)
    - Stakeholder mapping exercise to identify needs and abilities in all the African countries
    - Have a coordinator (e.g. secretariat / etc) and establish a community of practice. Establish a committee of network members to start the process and once funding is secured can establish a secretariat.
    - Possible name: African Carbon Observation Network (AfriCON)
    - Need to create Ocean Best Practises/Standard Operating Procedures for key GHG/carbon observations

3.4.5 Resources and limitations

The workshop participants listed the following requirements and limitations to achieving the immediate establishment of an African network of coastal biogeochemistry sites:

- Carbonate chemistry
    - Spectrophotometer for pH
    - Titrometer – alkalinity (ideal = auto titrator)
    - Samples fixed with mercury-chloride
    - CRMs only come from the USA (box of 24 = 4500 Euros – or only for 5 depending on customs); Quasimeme – internal standard (available from Europe – Netherlands for alkalinity and DIC)
    - Human resources: Dedicated person to conduct analyses. Also need other specialists to analyse other variables.
    - Countries with capabilities: Morocco, Sudan, Namibia, South Africa, Egypt, Mauritius, Mozambique, Nigeria, Kenya, Benin (limited), Tunisia (limited).
    - Import duties are prohibitive in many African countries.
- Blue carbon and sediments
    - Easy, relatively low-cost methods and most labs in African countries have the instruments
    - Drying oven, Ashing oven, balances
    - Corer (for offshore samples a multicorer is required, as well as a winch to retrieve the corer)
    - Mechanical Grinder
    - Samples for dating and elemental analyses must be sent overseas as there are currently no facilities in Africa. Consider establishing regional hubs.

- Human resources: Most research facilities in Africa do not have staff capacity to dedicate to coastal sample collection and analyses.
- Countries with capabilities: Tunisia, Mauritius, South Africa, Mauritius, Kenya, Egypt, Morocco, Mozambique, Seychelles, Tanzania, Ghana, Mauritania (starting) Cot d'voire, Togo (starting), Nigeria,
- Need additional capacity to get research going – enough interest from countries.
  - Infrastructure there, but in various institutions
- GHG Flux
  - Static chambers
  - Glass vials sent for GC analyses (samples can be sent overseas for analyses)
  - Flux towers – very expensive
  - Li-COR flux analyser – very expensive but techniques that utilise LI-COR such as eddy covariance and dynamic chambers provide excellent spatiotemporal coverage.
  - Water samples fixed with mercury-chloride sent overseas for analyses
  - Countries in Africa with capability: South Africa and Egypt
  - This research was identified as a big gap currently in Africa
- Near real-time data
  - Countries of capability: South Africa busy developing.
  - Moorings have numerous benefits and one way to grow the network is for industry to procure and use the platform to add their own sensors. An important partner could be the oil & gas industry.
  - Biogeochemistry Argo float data freely available, but data is limited to when a float passes a particular country. Another limitation is that these floats are often far offshore, not coastal.
- Research cruise carbon data
  - Countries that collect samples for carbonate chemistry (Morocco and Namibia, Nigeria, South Africa, Mauritius, Kenya, Guinea (mostly fisheries)
  - South Africa has pCO_2 underway sensor on SA Agulhas (Southern Ocean research)
  - For coastal areas – rather make use of smaller vessel

A major limitation highlighted by all the countries was dedicated technical staff capable of maintaining and operating the specialist instruments. It will be important to source funding for permanent posts for key researchers and technicians.

3.5 Appendices

3.5.1 Appendix 3A: List of attendees' countries and field of research

Country	Field of research
Morocco	Ocean acidification; biogeochemistry; pollution
Nigeria	Groundwater pollution - U of Helsinki
GUINEA	Marine chemistry, microplastics, etc.

Egypt	Trace gas emissions, GHG, soils
Namibia	Fisheries Biologist and Ocean Acidification
Benin	Marine biology, biodiversity - Cabo Verde
Kenya	KMFRI - research assistant
Tunisia	Carbon stock and flux in seagrass/salt marsh
Mauritius	University of Helsinki - Coral reefs
Cameroon	Oceanography, modeling, biogeochemistry
Benin	Marine technology

3.5.2 Appendix 3B: List of presenters' countries and field of research.

Country	**Field of research**
Greece	Ocean acidification and biogeochemistry
Norway	Ocean biogeochemistry
Mozambique	Corals reefs and fisheries
South Africa	Carbon stocks in seafans
South Africa	Biological oceanography
South Africa	Coastal biogeochemistry
South Africa	GHG Flux research
South Africa	Blue carbon in sediment

South Africa	Marine biology and Ocean acidification

3.5.3 Appendix 2C: Programme.

Time	Session
08:15 - 08:35	Opening and welcome
08:35 - 08:45	Housekeeping
08:45 - 09:15	Introductions and discussion on expertise and capacity
09:15 – 10:00	Tour of the Ocean Sciences Campus
10:00 - 10:30	Tea & snacks
10:30 - 11:15	Presentations by participants
11:15 - 12:00	Presentations by participants
12:00 - 13:00	Discussion on needs analysis for the region
13:00 - 14:00	Lunch
14:00 - 15:00	Presentations by participants
15:00 - 16:00	Advanced carbon observation network
16:00 - 16:15	Coffee break
16:15 - 17:00	Carbonate system best practice in the East Med. Heraklion coastal buoy
17:00-17:15	Presentation on field trip plans for Day 2

17:15 -	Transport to hotel
08:30 – 09:00	Meet at Ocean Sciences Campus
09:00 - 11:30	Group 1 to Swartkops Estuary
09:00-11:30	Group 2 to Algoa Bay
11:30- 14:00	Group 1 to Algoa Bay
11:30 -14:00	Group 2 to Swartkops Estuary
14:00 – 14:30	Lunch
14:30 - 16:00	Water and sediment sample prep in laboratory
16:00 - 16:15	Coffee break
	Sample analyses in laboratory
17:15 -	Transport to the hotel
09:00 - 10:00	Global Carbon Cycle and terrestrial flux
10:00 - 10:30	Tea & snacks
10:45 - 11:45	Blue carbon in the coastal environment
11:45 – 13:00	Measurement of GHG flux in estuaries
13:00 - 14:00	Lunch

14:00 – 14:30	The role of Rod Set Elevation Tables in carbon assessments + demonstration of RSET
14:30 - 15:30	GOA-ON in a box and results from South Africa
15:30 – 16:00	Continue with sediment analyses
16:00 - 16:15	Coffee break
16:15 - 17:00	Continue with sediment analyses & trip to Stromatolites (two groups)
17:00 -	Transport to hotel
08:00 – 10:00	
08:30 - 10:00	Discussion on regional needs
10:00 - 10:30	Tea
10:30 -11:00	ERDDAP data server and data management
11:00 – 13:00	Blue carbon and pH data analyses and presentation of data
13:00 - 14:00	Lunch
14:00 – 15:00	Discussion on resources and limitations
15:00 - 16:00	Design of a sustainable and operational observation network
16:00 - 16:15	Coffee break
16:15 - 17:00	Summary and way forward
17:00 - 19:00	Traditional South African braai (barbeque) on campus

06:30 – 12:30	Tour to Addo National Park
13:00 - 20:00	Transport to airport

4. Lessons learnt for implementation of coastal observing systems in Africa

4.1 Key lessons from the workshops

For implementation of coastal observing systems in Africa the following insights were gained, based on the feedback from the African participants in the Ostend workshop and discussions during the hands-on training course in Algoa Bay.

a. Coastal observation sites can be built in phases, starting with easily achieved and essential measurements. As resources become available, additional elements such as ocean CO_2 monitoring and more sophisticated atmospheric measurements can be incorporated. By focusing on these minimum requirements, African nations can establish a functional GHG emission and carbon observation network that provides valuable data for climate change mitigation strategies.
b. Implementation and use of low-cost sensors that adhere to Ocean Best Practices need to be practiced for manageable infrastructure budgets.
c. Fostering African collaborations can empower different countries to develop country-specific data, thus reducing reliance on generalized models or equations prevalent in the existing literature.
d. Mentorship programmes within Africa and with other international experts/entities is required for building capacity in analytical abilities and teach skills for data exchange at regional and international levels.
e. Mapping exercise on capability of countries and availability of equipment can alleviate the immense challenge of involving many African states in capacity building programs with duration long enough to ensure the trainees receive in depth training. Carbon research has many applications thus stakeholders must be included in this mapping exercise.
f. Implement and integrate standardized protocols for data collection, processing, and reporting to ensure consistency and comparability across different regions and monitoring sites. While developing the protocols, equipment limitations in each country must be considered.
g. Calibration of sensors is a key lacking capacity in the continent. This may be solved by developing regional calibration hubs which can also coordinate inter-laboratory comparisons.

4.2 Outlook and opportunities

Coastal marine ecosystems are recognized for their role in mediating global climate through their contribution as important sinks or sources of greenhouse gases (GHGs), such as carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). Some of the largest uncertainties in projecting future global environmental trends are attributable to an insufficient understanding of the physical and biogeochemical interactions and feedback between the ocean and atmosphere (IPCC 2019). While the atmospheric CO2 sink is reasonably well-constrained for the open ocean, the air–sea fluxes of GHGs from or to coastal ecosystems is not well acknowledged.

Training events will be an integral part of the process of further developing coastal observing systems capacity in Africa. In the future, it would be useful to map on what skills are needed to design and deliver targeted training events by the KADI project or similar. Furthermore, when evaluating the mapping results, it is important to try to consolidate existing capabilities in institutions/environments that can evolve in becoming regional competence centres. In this regard, it is important to mention that during the training events *stakeholder champions* – people with skills to measure basic coastal carbon variables working at institution with the necessary infrastructure – were identified in south, north, west of the continent. Collaborating with these stakeholder champions in future training events is recommended.

It maybe also be fruitful to align training events with international initiatives such as the WMO's 'Global Greenhouse Gas Watch, G3W' programme (Global Greenhouse Gas Watch (G3W)) which will aim to transform our current ability to measure and model GHG fluxes in support of policy making. This includes a significant ocean component, focused on measuring partial pressure for CO_2 (pCO_2) in surface seawater. In response, the Global Ocean Observing System (GOOS) has accepted a community lead initiative to start an observing network focused on surface pCO_2 observations known as SOCONET (Three emerging observing networks join the Global Ocean Observing System – Global Ocean Observing System). It is likely that both G3W and SOCONET will be implemented at regional to continental scales. Therefore, a potential opportunity would be holding training event(s) in preparation for this implementation. This could bring together African high-level actors on climate change, stakeholder champions, operators of observation infrastructures, national stakeholders etc. Key outputs from such workshop(s) include a white paper on the knowledge gaps identified in the coastal observation space (physical infrastructure and human capacity) and how to address this while aligning with the activities WMO/GOOS. Another opportunity is establishing a common platform for talks and discussions about carbon data and Greenhouse Gas emissions with members from all states of the African continent, etc.