Greenhouse Gas Observation & Climate-Smart Agriculture

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Training workshops in measurement, data management and quality control methodologies for the observation of greenhouse gas dynamics in the atmospheric, oceanic and terrestrial domains

SEACRIFOG Deliverable 4.4

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Ana López-Ballesteros[1], Johannes Beck [2], Ingunn Skjelvan [3], Abdirahman M. Omar[3], Truls Johannessen[4], Benjamin Pfeil[4], Rocio Castaño-Primo[4], Maren K. Karlsen[4], Matthew Saunders[1]

[1] Department of Botany, School of Natural Sciences, Trinity College Dublin (TCD)
[2] Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL)
[3]NORCE Norwegian Research Centre, Bjerknes Centre for Climate Research, Norway (NORCE)
[4]Geophysical Institute, University of Bergen, Bjerknes Centre for Climate Research, Norway (UoB)

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

SASSCAL
Southern African Science Service Centre for Climate Change and Adaptive Land Management

NORCE

Universitas Bergensis

Bjerknes Centre for Climate Research

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Lead beneficiary: Department of Botany, School of Natural Sciences, Trinity College Dublin (TCD)

Lead authors: Ana López-Ballesteros, alopezba@tcd.ie
Johannes Beck, johannes.beck@sasscal.org
Ingunn Skjelvan, insk@norceresearch.no
Abdirahman M. Omar. abom@norceresearch.no
Truls Johannessen. Truls.johannessen@uib.no
Benjamin Pfeil, benjamin.pfeil@uib.no
Rocio Castaño-Primo, rocio.primo@uib.no
Maren K. Karlsen, maren.veim@uib.no
Matthew Saunders, saundem@tcd.ie

Contributors: Mari Bieri, mari.bieri@thuenen.de
Christian Bruemmer, christian.bruemmer@thuenen.de
Gregor Feig, gregor@saeon.ac.za
Alecia Nickless, alecia.nickless@bristol.ac.uk
Knut Barthel, knut.barthel@uib.no
ElsheikhB.Ali, sheikhbashirali@yahoo.com

Submitted by: Veronika Jorch (Thuenen Institute)

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Executive Summary

Climate change represents the most important global challenge of the 21st century, as recognized by international institutions such as the United Nations Framework Convention on Climate Change (UNFCCC), which states that it is undeniably due to human activity including the emission of greenhouse gases (GHG) and land use/cover change. In the case of the African continent, there are still major observational gaps resulting in large uncertainties for most of the key variables used to study climate change, such as GHG sources and sinks, but also climate drivers and land management variables. The objective of the 'Supporting EU-African Cooperation on Research Infrastructures for Food Security and Greenhouse Gas Observations' (SEACRIFOG) project is to develop a concept for a pan-African Research Infrastructure (RI) for the systematic long-term in situ observation of the main climate forcing components together with their link with food security. SEACRIFOG is funded by the European Union (EU) through the Horizon 2020 Programme. One of the most important requirements to assure the success of this future RI is the development of the necessary human capacity with technical, theoretical and data analysis skillsets. For this reason, the SEACRIFOG project, and particularly Work Package (WP) 4 include tasks that focus on the organisation of capacity building activities which address the widespread methodologies utilized to measure variables related to GHG dynamics in the atmospheric, oceanic and terrestrial domains, as well as how to manage the derived data and perform quality control tests to ensure that the data produced is of the highest quality and can make a significant contribution to reducing the current uncertainties surrounding the GHG budget of the continent of Africa.

This report constitutes Deliverable 4.4 and was prepared by partners from Trinity College of Dublin (TCD), the Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL), NORCE the Norwegian Research Centre (NORCE) and the University of Bergen (UiB) as part of the outputs of WP4. This report describes the venue, content, participants' profiles and repositories for training materials associated with two workshops held at University of Bergen (Norway) and at University of Venda (South Africa). The former workshop covered methodologies generally used in oceanic monitoring, while the latter was focused on techniques applied to monitor GHG dynamics in the terrestrial and atmospheric domains.

The Bergen workshop on data management focused on providing to students, technicians and researchers the motivations and principles of data management. The workshop covered the key steps of the data life cycle, from new tools for data annotation, analysis and standardization, search engines and access to publicly available data, how to make their own data available, and how to store the data in a comprehensive form that always can be traced back to the original measurements ensuring transparency. The ocean workshop on data management was successful with the exception that not all invited participants were able to make it to Bergen due to visa complications that were outside of the WP team's control. For

future workshops, immigration authorities must be involved at an early stage in the planning phase.

The Eddy Covariance Winter School was a week-long workshop that offered an overview of the current status of GHG monitoring in Africa as well as training on the most appropriate techniques to measure GHG exchange in terrestrial (natural and managed systems) and atmospheric domains, with a special focus on the eddy covariance method. A substantial part of the workshop encompassed hands-on sessions focused on instrumentation, station setup and data processing. In order to maximise reach and minimise cost of this event, the SEACRIFOG consortium teamed up with the BMBF-funded project 'Ecosystem Management Support for Climate Change in Southern Africa' (EMSAfrica, www.emsafrica.org), resulting in an example of successful collaboration and capacity building between similar projects.

Overall, the capacity building activities organised by SEACRIFOG WP4 partners have directly reached a total number of 24 early-career researchers and technicians coming from Angola, Botswana, Nigeria, South Africa, Sudan, Zimbabwe and Zambia.

List of Abbreviations

ARS	Agricultural Research Council
BCDC	Bjerknes Climate Data Centre
BMBF	German Federal Ministry of Education and Research
CSIR	Council of Scientific & Industrial Research
D	Deliverable
DIVA	Data Interpolating Variational Analysis
DOI	Digital Object Identifier
EC	Eddy Covariance
EFTEON	Expanded Freshwater and Terrestrial Environmental Observation Network
EMSAfrica	Ecosystem Management Support for Climate Change in Southern Africa
EOV	Essential Ocean Variables
EU	European Union
FAIR	Findable Accessible Interoperable Re-usable
GHG	Greenhouse Gas
GLODAP	GLobal Ocean Data Analysis Product
ICOS	Integrated Carbon Observation System
IMR-RSU	Institute of Marine Research, Red Sea Unniversity, Sudan
netDF	Network Common Data Form
NODC	National Oceanographic Data Centres
NORCE	NORCE Norwegian Research Centre
ODV	Ocean Data View
RI	Research Infrastructure
SAEON	South African Environmental Observation Network
SASSCAL	Southern African Science Service Centre for Climate Change and Adaptive Land Management
SEACRIFOG	Supporting EU-African Cooperation on Research Infrastructures for Food Security and Greenhouse Gas Observations
SOCAT	Surface Ocean CO2 Atlas
SPACES	Science Partnerships for the Adaptation/Adjustment to Complex Earth System Processes in Southern Africa
TCD	Trinity College Dublin
UiB	University of Bergen
UNFCCC	United Nations Framework Convention on Climate Change
WP	Work Package

1 Introduction

1.1 Background

There is currently a lack of representative, systematic and harmonised observations of greenhouse gas (GHG) sources and sinks and related variables across the variety of natural and human-disturbed biomes in Africa (López-Ballesteros et al., 2018). This limits our understanding of the biogeochemical and biophysical processes underlying climate change, its impacts, feedback loops and tipping points across the African continent and surrounding oceans, but also increases the uncertainty of the African contribution to the global carbon (C) cycle and climate forcing (Kulmala, 2018). The current and projected socio-economical trajectories for the continent (i.e. the increasing trend of urbanisation as well as population and economic growth) together with the vulnerability of natural and managed ecosystems to the adverse impacts of climate change make the development of a pan-African GHG research infrastructure (RI) an urgent societal and scientific priority.

The principal goal of the EU H2020 funded project 'Supporting EU-African Cooperation on Research Infrastructures for Food Security and Greenhouse Gas Observations' (SEACRIFOG; www. seacrifog.eu) is to develop a concept for a pan-African RI for the systematic long-term in situ observation of the main climate forcing components, such as GHG sources and sinks together with their links with food security. The design of this RI takes into account the atmosphere-land-ocean continuum as well as both natural and disturbed ecosystems (e.g. agricultural systems or urban settlements). Some of the most relevant strategic aspects of this development process are: 1) interoperability, in order to be coherent and facilitate integration with existing regional and global RIs, 2) flexibility, to enable the long-term evolution and integration of new variables, sites or methodologies as determined by the local scientific communities, and 3) harmonization, to be interdisciplinary and produce useful information for a wide range of scientific disciplines and stakeholders. SEACRIFOG is part of the INFRASUPP Work Programme 2016-2017 ('Policy and international cooperation measures for research Infrastructures') of the EU's H2020 Funding Programme. In accordance with the objectives of this work programme, SEACRIFOG aims to "help to develop better coordination and cooperation of European research infrastructures with their African counterparts, ensuring global interoperability and reach, and pursuing international agreements on the reciprocal use, openness or co-financing of infrastructures".

In this regard, Work Package 4 (WP4) of the SEACRIFOG project is focused on the 'improvement of technical harmonization and data quality in the current environmental monitoring and experimentation'. This WP is led by Trinity College Dublin in cooperation with the contributing partner institutions Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL), NORCE the Norwegian Research Centre and the University of Bergen (UiB). The present report constitutes Deliverable 4.4 under Task 4.3 of SEACRIFOG

WP4. The main goal of this task is to provide and disseminate best practices guidelines ensuring that the operation of observational networks and associated data collection, quality control and reporting formats can be harmonized across the African region, and with international research networks. According to the project proposal, the workshops were thematically organised with NORCE and UiB responsible for the marine workshops and data harmonization, while TCD and SASSCAL coordinated the terrestrial and atmospheric workshops. The content of these capacity building workshops builds on previous SEACRIFOG WP4 Deliverables, where the essential variables to be measured by the future pan-African RI were identified (D4.1[1]), corresponding data availability was assessed (D4.2[2]) and related methodological protocols were collected and evaluated (D4.3[3]).

Two marine workshops were organized by NORCE and UiB and held in Bergen in April 2019 and were run back to back: one on analytical oceanography and another on data management. The first workshop on analytical oceanography is a deliverable of WP5 (D5.3) in the SEACRIFOG project and will be described in a separate report. The second on data management is a deliverable of WP4 (D4.4 this report) and will be presented in the paragraphs below. Please note that some of the activities and material, e.g. the outreach activities and theory of physical and chemical oceanography are similar for the two workshops. The two marine workshops were closely connected in the sense that the participants were presented with the same introductory material during the first days which formed the basis for both workshops.

NORCE and UiB have cooperated with Institute for Marine Research, Red Sea University (IMR-RSU) in Port Sudan since 2005, focusing on biogeochemistry of the Red Sea, ocean physics, the general carbon cycle, deoxygenation and ocean acidification. The workshop on data management aimed to facilitate a collaborative network of students, technicians and researchers from east African countries neighbouring the Red Sea and Gulf of Aden. In principle the workshop had the potential to include all ocean facing countries in Africa. In this sense, the workshop can be regarded as a pilot exercise and the subsequent workshops could include more African countries depending on resource availability. The theme for such an extended event could be: “The impact of global warming on ocean physics, ocean acidification, deoxygenation particularly in upwelling areas as the Benguela Current, the carbon cycle, nutrient and food supply along the African Coastal Areas”.

1.2 Document purpose

This document aims at describing the different workshops that constitute SEACRIFOG Deliverable 4.4 as well as SEACRIFOG Milestones 15, 16 and 19: the preparatory phase, the realization, and the material developed, with the aim to hold similar workshops in the future.

[1] https://www.seacrifog.eu/fileadmin/seacrifog/Deliverables/2018.08.18_SEACRIFOG_Deliverable_4.1_doi.pdf
[2] https://www.seacrifog.eu/fileadmin/seacrifog/Deliverables/2019.01.31_SEACRIFOG_Deliverable_4.2_doi.pdf
[3] https://www.seacrifog.eu/fileadmin/seacrifog/Deliverables/Lopez-Ballesteros_et_al._2019_SEACRIFOG_D4.3_doi.pdf

2 Training workshop on GHG observation in the oceanic domain

2.1 Workshop description and content

The data management workshop took place at the Geophysical Institute, University of Bergen (UiB), Norway (Figure 1). The aim of the workshop was to provide to students, technicians and researchers the motivations and principles of data management, and to touch upon most of the steps of the data life cycle, from new tools for data annotation, analysis and standardization, search and access to publicly available data and how to make their own data available to other researchers. The workshop focused on some of the Essential Ocean Variables (EOVs: https://www.climate.gov/maps-data/primer/ocean-oceanic-climate-variables), and prior to the data management workshop, oceanographic data were collected from a fjord close to Bergen as part of the workshop on analytical oceanography . This data set contributed to the material used during the data management workshop. The workshop consisted of lectures, practical sessions with hands-on training, and discussions. The schedule can be found in Table 1, and the description of it in detail below.

Figure 1. Geophysical Institute, UiB, where the workshop took place.

The Bjerknes Climate Data Centre was presented (BCDC) as an example of data management in natural sciences in practice. Further, some of the projects (e.g. ICOS as a Research Infrastructure within EU) and data products (SOCAT, GLODAP) that the centre is involved in were presented, as well as the varied data sources and infrastructures that BCDC uses. Then the participants learnt about the legal framework that data generated from public funding has to be made freely available and were introduced to the fundamental concepts in data management: what is data and which types of data exist, metadata and its importance to

describe the data, and DOIs (Digital Object Identifier) as the most common permanent identifier for data sets..

The participants were taught in aspects of presentation tools, metadata, data quality, open data access, data storage, how to find new data, global data efforts, and the theoretical basis of physical and chemical oceanography.

As an example of an open source, specific software for ocean data visualization, annotation, and gridding, we presented the students with Ocean Data View (odv.awi.de). As a practical example, the ODV version of GLODAPv2 was chosen. The students learnt about the different data types it supports (profile, time series, section, surface), sub-setting of data by geographical area, time slice or quality flag, visualization options (scatter, surface plots), derived variables calculation tools (for example, calculation of two carbon variables from the other two, or seawater density), and gridding algorithms like DIVA. After an introductory presentation, the participants should explore the GLODAPv2 ODV dataset as a ready-to-use example; unfortunately, limitations in computing power and computer handling made it difficult for the students to fully explore the capabilities of ODV. In addition, students created an ODV version of the data they generated during the analytical oceanography workshop and made property-property plots for their cruise report.

The concept of open data was introduced as well as the need for data reusability and the criteria that define data as FAIR. There was some repetition and extension of the concepts presented during the first session, with examples particularly based on the participants industry and academic experience.

The participants were presented with a variety of sources, from which to retrieve data, and given tips on how to optimize their data search. It was touched upon how data from different disciplines or types are being archived in different places and formats, the differences between data archives, data portals and data synthesis, and some of the issues they will run into when searching for data (e.g. version conflicts, unstandardized data files, only metadata available, restrictions). The presentation was followed by a hands-on session where the students searched for data that was of interest to them.

Furthermore, the participants learned where they could publish their own data, focusing on National Oceanographic Data Centres (NODCs), where many scientists have an obligation to deposit their data, and Pangaea (pangaea.de), where a team of curators will ensure their data is standardized and properly documented. The data series from the analytical oceanography workshop will be published in Pangaea.

During the workshop a short introduction to Jupyter notebook and Python3 was given as examples of different tools for data handling, that improve reproducibility. Through a live-coding session, it was presented how python may be used to import a csv-file or netCDF file and some popular toolboxes to interact with and process the imported data. Pandas, matplotlib, datetime and numpy were also mentioned. The participants seemed interested and

engaged during the session. Limitations in time, computer-power and experience made this session slightly challenging.

The following lecturers contributed to the data management workshop:

- Elsheikh B. Ali - PhD and head of Institute of Marine Research, Red Sea University, Sudan
- Knut Barthel - associate professor, Geophysical Institute, University of Bergen, Norway
- Rocio Castaño-Primo - data manager, Geophysical Institute, University of Bergen, Norway
- Truls Johannessen – professor, Geophysical Institute, University of Bergen, Norway
- Maren K. Karlsen - data manager, Geophysical Institute, University of Bergen, Norway
- Abdirahman M. Omar - senior researcher, NORCE Norwegian Research Centre, Norway
- Benjamin Pfeil - data manager, Geophysical Institute, University of Bergen, Norway
- Ingunn Skjelvan - senior researcher, NORCE Norwegian Research Centre, Norway

The gender distribution between the lecturers were as follows: 3 of 8 (38%) were female.

Table 1. Detailed schedule of the two SEACRIFOG Workshops on analytical oceanography and data management, which took place in Bergen, Norway during the period 1st to 10th April 2019. The introductory material during the first days were common for both workshops, while the remaining of the data workshop took place during 8th to 10th April.

DATE/TIME	ACTIVITY	LECTURER	PLACE
Monday 1st April			
9:00-11:00	Welcome Course overview Presentation of participants and institutions - Institute of Marine Research, Red Sea University - Faculty of Marine Sciences and Fisheries, Red Sea University - East African University - Berbera Marine and Fisheries Academy - Benadir University	Truls Johannessen Ingunn Skjelvan All participants	Inger Brun
11:00-11:15	***Break***		
11.15-13:00	Physical oceanography theory	Knut Barthel	Inger Brun
13:00-14:00	***Lunch***		
14:00-16:00	Sampling strategies Cruise preparation - mooring	Ingunn Skjelvan Tor de Lange	Inger Brun / Alleg 55
16-16:15	***Break***		
16:15-18:00	Continuation moorings Cruise report	Tor de Lange Ingunn Skjelvan	
Tuesday 2nd April			
9:00-11:00	Chemical oceanography theory	Elsheikh B. Ali	Inger Brun
11:00-11:15	***Break***		
11.15-13:00	Continuation moorings	Tor de Lange	Alleg 55

13:00-14:00	***Lunch***		
14:00-16:00	Continuation moorings	Tor de Lange	Alleg 55
16-16:15	***Break***		
16:15-18:00	Lab safety Cruise preparation – chemistry and discrete sampling	Kristin Jackson Kristin Jackson	Jahnebakken 3
Wednesday 3rd April			
9:00-17:00	Cruise to Eidsvågen Prepare and deploy mooring Collect discrete samples	 Tor de Lange Kristin Jackson	Nykirkekaien, *R/V Bratt-strøm*
Thursday 4th April			
9:00-11:00	Lab analyses	Kristin Jackson	Jahnebakken 3
11:00-11:15	**Break**		
11.15-12:10	Lab analyses	Kristin Jackson	Jahnebakken 3
13:00-14:00	***Lunch***		
14:00-16:00	Lab analyses	Kristin Jackson	Jahnebakken 3
16-16:15	***Break***		
16:15-18:00	Lab analyses Carbon calculation software (CO2SYS) Quality check of data Cruise report	Kristin Jackson Abdirahman M. Omar Abdirahman M. Omar Ingunn Skjelvan	Jahnebakken 3 Inger Brun
Friday 5th April			
9:00-14:00	Cruise to Eidsvågen Retrieve mooring Collect discrete samples	 Tor de Lange Kristin Jackson	Nykirkekaien, R*/V Bratt-strøm*
14:00-16:00	***Free time***		
16:00-18:00	Post cruise activities	Tor de Lange	
Saturday 6th April			
9:00-11:00	Analyses of discrete samples Explore data Cruise report	Kristin Jackson Abdirahman M. Omar Ingunn Skjelvan Elsheikh B. Ali	Jahnebakken 3 Inger Brun
11:00-11:15	**Break**		
11:00-13:00	Continue cruise report	Abdirahman M. Omar Ingunn Skjelvan Elsheikh B. Ali	
13:00-14:00	***Lunch***		
Sunday 7th April - Free time			
Monday 8th April			
9:00-11:00	Introduction data management	Benjamin Pfeil	Helland-Hansen
11:00-11:15	***Break***		
11.15-13:00	Ocean Data View (ODV) - introduction and hands on	Benjamin Pfeil	Helland-Hansen

13:00-14:00	***Lunch***		
14:00-16:00	ODV continuation	Benjamin Pfeil	Helland-Hansen
18:00	Deadline for cruise report	Ingunn Skjelvan	
Tuesday 9th April			
9:00-11:00	Open data	Rocio Castaño-Primo	Helland-Hansen
11:00-11:15	***Break***		
11.15-13:00	Access to data sources	Benjamin Pfeil	Helland-Hansen
13:00-14:00	***Lunch***		
14:00-15:00	How to make your own data available	Benjamin Pfeil	Helland-Hansen
15:00-16:00	Travel claims – forms to fill out	Ingunn Skjelvan	
18:00	Deliver final cruise report	Ingunn Skjelvan	
Wednesday 10th April			
9:00-11:00	Other tools for data handling: Jupyter notebook	Maren K. Karlsen	Helland-Hansen
11:00-11:15	***Break***		
11.15-13:00	Data management in action: RI ICOS	Benjamin Pfeil	Helland-Hansen
13:00-14:00	***Lunch***		
14:00-15:00	Wrap up	Ingunn Skjelvan Abdirahman M. Omar Elsheikh B. Ali	Helland-Hansen

2.2 Participants

The proposed plan was to arrange workshops at IMR-RSU. Unfortunately, the plan had to be changed because IMR-RSU were not able to become a partner of the SEACRIFOG project. Based on this, the decision was taken to move the workshop to Bergen. Due to high travel expenses, the workshop could only accommodate a maximum of 8 participants in comparison to the planned 28 in Port Sudan.

The workshop was announced in February 2018 by e-mail to research communities in Sudan, Djibouti, and Somalia. By the deadline in April 2018, 21 applicants from Somalia and Sudan had announced their interest to NORCE by submitting their application including a CV and recommendation letters from their home institutions. A panel consisting of lecturers from NORCE and IMR-RSU decided the final admission and the selection was performed based on the candidate's education, their current work and an evaluation of how useful the workshop would be for their employer. Seven participants from 5 institutions in Somalia and Sudan were selected and in September 2018, all of them received invitation letters to prepare for visa applications.

Due to circumstances out of the project team's control, 3 Somalian participants did not receive their visa in time, and thus the workshop took place with only 4 participants, all of them from Sudan (Figure 2). The participant list including their home institution and gender can be found in Annex I, the participants who did not get visas in time are also included in this table. The 3 Somalians have since been given access to all the course material via the SEACRIFOG project web site.

Out of the 7 participants accepted, 3 were female (43%), and of the 4 actual participants, 3 were female (75%). Four of the 7 accepted participants were technicians, 2 were marine science lecturers, and one was a PhD student.

Figure 2. Participants and some of the teachers at the data management workshop. Permission has been granted by the participants to include their images in this report.

2.3 Workshop materials

The workshop materials are all available via the SEACRIFOG webpage (https://www.seacrifog.eu/news-events/news/training-workshop-on-analytical-oceanography-and-data-management-by-seacrifog/). The site is password protected and the access can be granted by the project office. The materials consist of presentations from the lecturers as well as from the participants, manuals and instructions, links to software for data presentation and data handling, and oceanographic data which were managed during the workshop. During the workshop the participants were trained in using data management tools like Ocean Data View (ODV) and the open-source software Jupyter.

2.4 Outreach and communication activities

The workshops in Bergen were communicated primarily through the SEACRIFOG webpages and twitter accounts:

https://www.seacrifog.eu/news-events/news/training-workshop-on-analytical-oceanography-and-data-management-by-seacrifog/

https://twitter.com/SEACRIFOG

Further, an interview of the Norwegian SEACRIFOG PI from NORCE, Abdirahman M. Omar was undertaken by students from the SEACRIFOG partner TCD (Trinity College in Dublin, Ireland) as part of their science communication project, and this will be made available soon.

3 Training workshop on GHG observation in the atmospheric and terrestrial domains

3.1 Workshop description and content

The Eddy Covariance Winter School was held from Monday 10th to Friday 14th June 2019, in the Vuwani Science Resource Centre of the University of Venda, Limpopo Province (South Africa; see Figure 3).

Figure 3. Location of the Vuwani Science Resource Centre of the University of Venda (Limpopo Province, South Africa), where the Winter School took place.

The main aim was to support young researchers to initiate new projects and to take advantage of the planned and existing Eddy Covariance infrastructures. Therefore, the target audience corresponded to students and early-career researchers (MSc and PhD students and postdoctoral researchers), as well as technicians and engineers, primarily from Southern Africa (Angola, Botswana, Namibia, South Africa and Zambia).

This training school was co-organised by the SEACRIFOG project and the EMS Africa project (Ecosystem Management Support for Climate Change in Southern Africa; www.emsafrica.org), which is funded by the BMBF (German Federal Ministry of Education and Research) via the programme SPACES (Science Partnerships for the Adaptation/Adjustment to Complex Earth System Processes in Southern Africa) under the FONA (Research for Sustainable Development)

framework. The collaboration between the two projects allowed for the participation of a higher amount of participants, the content coverage and the optimisation of financial resources dedicated to capacity building activities in each project separately.

The course offered an overview of the current status of GHG monitoring in Africa as well as technical training on the related measuring techniques, with a special focus on eddy covariance. Currently, there is an eddy covariance station installed in the Vuwani Science Resource Centre that allowed for in situ practical training on instrumentation and station setup (see Figure 4). In addition, the lectures also included other measurement techniques such as atmospheric GHG monitoring and modelling, the chamber-based methodologies as well as other approaches to measure livestock GHG emissions. Detailed programme can be found in Table 2.

Figure 4. Vuwani Science Resource Centre of the University of Venda (right photo). Eddy covariance station installed in the vicinity of the centre that was used for training purposes.

Recent results from ongoing projects developed in South Africa and focused on the combination of flux data with carbon stock information and remote sensing products were also presented by independent researchers from several South African institutions. Overall, the course encompassed lectures, hands-on sessions, interactive workshops, discussions, and opportunities for networking and personal feedback. The participating lecturers were the following:

- Johannes Beck (Southern African Science Service Centre for Climate Change and Adaptive Land Management, SASSCAL, Namibia)
- Christian Brümmer (Thünen Institute for Climate-Smart Agriculture, Germany)
- Gregor Feig (South African Environmental Observation Network/ Expanded Freshwater and Terrestrial Environmental Observation Network, EFTEON/SAEON, South Africa)

- Ana López-Ballesteros (Trinity College Dublin, Ireland)
- Graham Von Maltitz (Council of Scientific & Industrial Research, CSIR, South Africa)
- Amukelani Maluleke (Council of Scientific & Industrial Research, CSIR, South Africa)
- Mohau Mateyisi (Council of Scientific & Industrial Research, CSIR, South Africa)
- Alecia Nickless (University of Bristol, United Kingdom)
- Tony Palmer (Agricultural Research Council, ARS, South Africa)
- Phumudzo Tharaga (University of the Free State, South Africa)
- Humbelani Thenga (Council of Scientific & Industrial Research, CSIR, South Africa)

Table 2. Detailed programme of the Eddy Covariance Winter School celebrated from 10th to 15th June 2019 in Vuwani (South Africa).

Monday 10th June			
Time	**Session**	**Session leader**	**Location**
9:00	Introduction & **Official opening** by the course hosting University partners	Natasha Potgieter, Dean Eric Maluta, Course Host University of Venda	Auditorium
9:30	Introduction to the **content & aims** of the course	Christian Brümmer, Thünen-AK	Auditorium
9:45	**Introduction round**: 2-minute power point presentations by teachers and course participants	Mari Bieri, Thünen-AK	Computer Room
11:00	TEA BREAK & NETWORKING		Courtyard
11:45	General overview of the current status of **environmental observation in Africa** – the SEACRIFOG project	Johannes Beck, SASSCAL	Computer Room
12:15	Which variables do we need to measure to improve **global and African GHG budgets** and estimate **climate forcing components**?	Johannes Beck	Computer Room
12:45	LUNCH BREAK		Courtyard
14:00	Current **data availability**: monitoring networks & their spatial representativeness	Johannes Beck	Computer Room
14:45	Introduction to **EFTEON**: The Expanded Freshwater and Terrestrial Environmental Observation Network	Gregor Feig, SAEON/EFTEON	Computer Room
15:30	TEA BREAK & NETWORKING		Courtyard
16:00-17:00	**Methodologies to measure GHG emissions** in the terrestrial domain (*other than Eddy Covariance*)	Ana López-Ballesteros, TCD	Computer Room
Tuesday 11th June			
Time	**Session**	**Session leader**	**Location**
9:00	**Fundamentals of atmospheric monitoring**: site considerations and instrumentation	Alecia Nickless	Computer Room
10:00	Inverse modelling: Introduction to **atmospheric inversions** with examples of **applications in Africa**	Alecia Nickless	Computer Room
11:00	TEA BREAK & NETWORKING		Courtyard
11:45	**Eddy covariance** - introduction	Christian Brümmer	Computer Room

12:45	LUNCH BREAK		Courtyard
14:00	Eddy covariance - **instruments** session	Christian Brümmer, Jean-Pierre Delorme, Jens Jüdt (Thünen-AK), Humbelani Thenga, Amukelani Maluleke (CSIR)	Computer Room/Vuwani tower (outside)
16:00	TEA BREAK & NETWORKING		Courtyard
16:30-17:15	Corrected **CO_2 fluxes** for the Great Fish Thicket	Tony Palmer (ARC)	Computer Room
Wednesday 12th June			
Time	**Session**	**Session leader**	**Location**
9:00-10:30	Parallel sessions: *the group will be divided into two parts, and each will attend both of the hands-on sessions* (1 and 2) "Hands-on" session 1: **Setting up and running an Eddy Covariance system**	Christian Brümmer, Jean-Pierre Delorme, Jens Jüdt, Humbelani Thenga, Amukelani Maluleke	Computer Room/ Outside area
9:00-10:30	"Hands-on" session 2: **Setting up an Automatic Weather Station (AWS)**	Gregor Feig	Outside area
10:30	TEA BREAK & NETWORKING		Courtyard
11:15-12:45	"Hands-on" session 1: **Setting up and running an Eddy Covariance system**	Christian Brümmer, Jean-Pierre Delorme, Jens Jüdt, Humbelani Thenga, Amukelani Maluleke	Computer Room/ Outside area
11:15-12:45	"Hands-on" session 2: **Setting up an Automatic Weather Station (AWS)**	Gregor Feig	Outside area
12:45	LUNCH BREAK		Courtyard
14:00	Introduction: Working with cleaned flux data on **model evaluation**	Mohau Mateyisi (CSIR)	Computer room
14:30	Hands-on session with R: Working with cleaned flux data on model evaluation (*participants need laptops with R installed*)	Mohau Mateyisi	Computer room
15:30	TEA BREAK & NETWORKING		Courtyard
16:00-17:30	Hands-on session with R: Working with cleaned flux data on model evaluation	Mohau Mateyisi	Computer room
17:30 →	Joint dinner/ evening programme/ excursion TBA		
Thursday 13th June			
Time	**Session**	**Session leader**	**Location**
9:00	EC project at the cherry plantations of the Eastern Free State (exact title TBA)	Phumudzo Tharaga (University of the Free State)	Computer room
10:45	TEA BREAK & NETWORKING		Courtyard
11:30	Skukuza site as an example of research questions conducted at **long term flux measurement sites** in Africa	Gregor Feig	Computer room
12:45	LUNCH BREAK		Courtyard

14:00-15.30	Parallel sessions 1 and 2 – group divided into two Hands-on session 1: **Soil chamber measurements** (with theory introduction)	Ana López-Ballesteros	Computer room
14:00-15:30	Hands-on session 2: From raw data to **processed quality assured fluxes**	Christian Brümmer, Humbelani Thenga, Amukelani Maluleke	Computer room
15:30	TEA BREAK & NETWORKING		Courtyard
16:15-17:45	Hands-on session 1: **Soil chamber measurements** (with theory introduction)	Ana López-Ballesteros	Computer room
16:15-17:45	Hands-on session 2: From raw data to **processed quality assured fluxes**	Christian Brümmer, Humbelani Thenga, Amukelani Maluleke	Computer room

Friday 14th June			
Time	**Session**	**Session leader**	**Location**
9:00	Using flux data in **national terrestrial carbon accounting**	Graham Von Maltitz (CSIR)	Computer room
10:00	Personalized support sessions (or TBA)	All course teachers	Computer room/Board room/TBA
11:00	TEA BREAK & NETWORKING		Courtyard
11:30	Personalized support sessions (or TBA)	All course teachers	Computer room/Board room/TBA
12:30	LUNCH BREAK		Courtyard
14:00	Final session: wrap-up, closing discussion, next steps & course feedback	Christian Brümmer & Gregor Feig	Computer room
15:00-18:00	Final ceremony; handing out course certificates; joint dinner & drinks		Science Centre

3.2 Participants

Registration for the course opened in April 2019 and was distributed via email channels, project websites, various fora, and a printable poster. Registrations were collected by the Thünen-AK team, and application documents included CV, motivational letter, and a supporting letter from supervisor/senior academic explaining the need for a funded position. A panel was formed from course lecturers and hosts (University of Venda, Thünen-AK, SAEON/EFTEON and SEACRIFOG partners) to decide on final admissions.

The participants of the course were students, technicians and early-career researchers from southern African countries. Out of the 20 participants, 9 were women (45%) and 11 men (55%). The gender and institutions of all the participants can be found in Annex II.

Figure 5. All participants, including attendants and lecturers, of the Eddy Covariance Winter School 2019.

Many participants (60%) came from South African universities and research institutions, although 40% came from other countries of Southern Africa (see Figure 6 below).

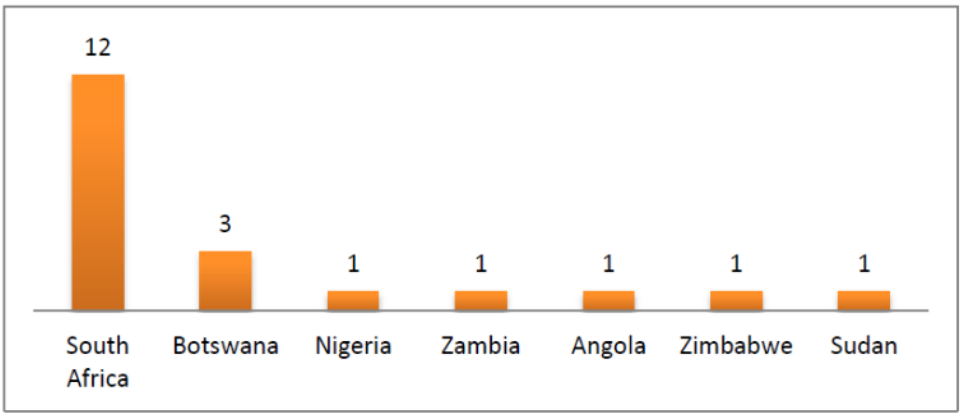

Figure 6. Origin of the participants of the Eddy Covariance Winter School 2019.

In regards to the career stage, most of the attendants were Master (45%) or PhD (25%) students, while higher career stages (i.e. > post-doctoral) only represented 15% of the audience (see Figure 7).

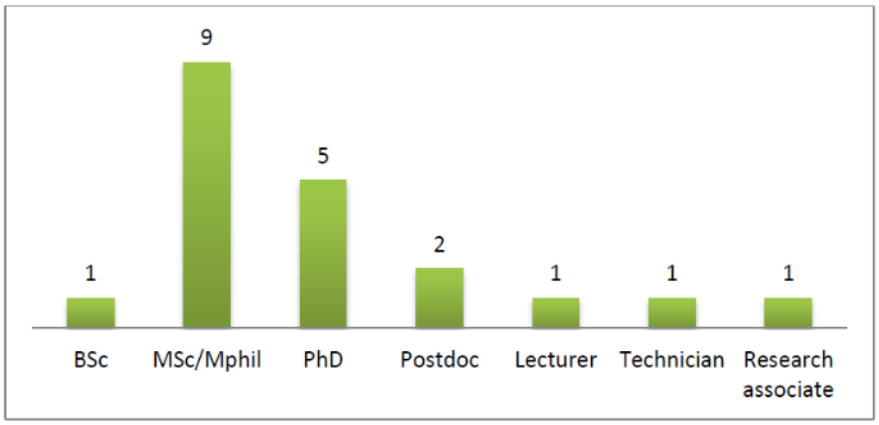

Figure 7. Career stage of the participants of the Eddy Covariance Winter School 2019.

3.3 Assessment survey

An online survey was sent to the participants during the last day of the winter school in order to anonymously collect feedback from them for the purposes of internal reporting and developing the content of future courses. Currently, the survey is still open in order to gather the maximum number of forms. The survey results will feed future capacity buildings of both SEACRIFOG and EMS Africa projects.

3.4 Workshop materials

Lecture presentations are publicly available at the SEACRIFOG project website, under the "Publications tab" and within the "Course Material" menu (link). The materials consist of presentations from the lecturers participating in the SEACRIFOG project, which corresponds to the following sessions:

- General overview of the current status of environmental observation in Africa – the SEACRIFOG project (by Johannes Beck, SASSCAL)
- Which variables do we need to measure to improve global and African GHG budgets and estimate climate forcing components? (by Johannes Beck, SASSCAL)
- Methodologies to measure GHG emissions in the terrestrial domain (by Ana López-Ballesteros, TCD)
- Soil chamber measurements (by Ana López-Ballesteros, TCD)
- Fundamentals of atmospheric monitoring: site considerations and instrumentation(by Alecia Nickless, University of Bristol)
- Inverse modelling: Introduction to atmospheric inversions with examples of applications in Africa (by Alecia Nickless, University of Bristol)

Permission is pending for additional presentations and materials from non-SEACRIFOG lecturers, which may be added in future.

3.5 Outreach and communication activities

During the duration of the Winter School, several lecturers and attendants were sharing real-time information and pictures showing some of the lectures content as well as practical exercises of the hands-on session. Most of these tweets can be overviewed by using the hashtag #ECWinterSchool or alternatively, in the tweeter accounts of both projects, SEACRIFOG (@SEACRIFOG) and EMS Africa (@EMSAfrica).

Furthermore, some of the lecturers were interviewed in a half-hour show in the radio Phalaphala FM station (see Figure 8), which is a South African radio station operating through SABC, South Africa's government owned national broadcaster. Phalaphala broadcast is in the Tshivenda language and can be received mainly in Gauteng and Limpopo provinces.

Figure 8. Interviewed participants in the Phalaphala FM radio station. From right to left: Humbelani Thenga, Eric Maluta, Mari Bieri and Johannes Beck.

References

Kulmala, M., 2018. Build a global Earth observatory. Nature 553, 21–23. https://doi.org/10.1038/d41586-017-08967-y

López-Ballesteros, A., Beck, J., Bombelli, A., Grieco, E., Lorencová, E.K., Merbold, L., Brümmer, C., Hugo, W., Scholes, R., Vačkář, D., Vermeulen, A., Acosta, M., Butterbach-Bahl, K., Helmschrot, J., Kim, D.-G., Jones, M., Jorch, V., Pavelka, M., Skjelvan, I., Saunders, M., 2018. Towards a feasible and representative pan-African research infrastructure network for GHG observations. Environ. Res. Lett. 13, 085003. https://doi.org/10.1088/1748-9326/aad66c

Annex I

Participant number	Gender	Institute
1	M	Institute of Marine Research, Red Sea University, Sudan
2	F	Faulty of Marine Sciences and Fishery, Red Sea University, Sudan
3	F	Faulty of Marine Sciences and Fishery, Red Sea University, Sudan
4	F	Faulty of Marine Sciences and Fishery, Red Sea University, Sudan
5	M	East African University, Bosaso, Puntland, Somalia
6	M	Berbera Maritime and Fisheries Academy, Berbera, Somaliland
7	M	Faculty of Geosciences and Environment, Benadir University, Mogadishu, Somalia

Participant number 1 to 4 took physically part of in the workshop, while participant 5-7 received the workshop material afterwards.

Annex II

Participant number	Gender	Institute
1	M	The Afromontane Research Unit (ARU), QwaQwa Campus of the University of the Free State
2	M	University of Botswana
3	M	South African Environmental Observation Network (SAEON), Fynbos Node
4	F	Landscape Ecology, University of the Witwatersrand
5	M	University of Venda
6	F	Rhodes University, Institute for Water Research
7	F	Expanded Freshwater and Terrestrial Environmental Observation Network (EFTEON)
8	M	University of Witwatersrand
9	M	University of Venda
10	F	University College Dublin, Justus Liebig University Giessen
11	M	University of KwaZulu-Natal, School of Agricultural, Earth and Environmental Sciences/College of Agriculture, Engrineering and Science
12	M	University of Botswana, Department of Physics, Physics-with-Meteorology Degree Programme
13	F	South African Environmental Observation Network (SAEON)
14	M	South African Environmental Observation Network (SAEON)
15	F	University of Venda
16	M	University of Zambia
17	F	University of Venda
18	F	University of Botswana
19	M	Council of Scientific & Industrial Research (CSIR)
20	F	Walter Sisulu University