[Version: 03 June 2019]

Training course session descriptions

Day 1, Monday, June 10

Session 1: Scientific importance of instrumenting our oceans
Instructor: Maciej Telszewski
The lecture will be on the scientific importance of instrumenting our oceans, with a particular focus on biogeochemical measurements which are needed to describe key issues and phenomena of societal interest, e.g. carbon cycle, ocean acidification, deoxygenation, harmful algal blooms. You will be introduced to the Framework for Ocean Observing and the concept of Essential Ocean Variables as a means of globally setting requirements for sustained ocean observations. Maciej will talk about the importance of developing the global network of marine biogeochemistry observations using autonomous platforms on top of the more traditional ship-based and fixed-point observations. Presenting the vision for an integrated Global Ocean Observing System that delivers essential ocean information to the society, the talk will emphasize the need for multi-platform and multi-disciplinary approach to observations.

Session 2: Coordinated global observing networks for marine biogeochemistry
Instructor: Maciej Telszewski
This lecture will introduce the course participants to the current landscape of coordinated marine biogeochemistry observations in the global ocean, with a particular focus on different types of platforms around which various observing networks are formed.

Session 3: Sensors – inside out (Part 1: oxygen and bio-optical sensors)
Instructors: Henry Bittig, Nathan Briggs, Giorgio Dall'Olmo
This session will be divided in two parts and will be composed of several lectures on oxygen sensors (by Henry Bittig) and on bio-optical sensors (by Nathan Briggs and Giorgio Dall'Olmo).

The oxygen lectures will include the following topics:
- Physical/chemical properties of O_2 and why measure O_2
- Principles to measure O_2 (wet chemical, electrochemical, quenching)
- Oxygen optodes in detail: Sensing foil and equilibration between foil and seawater
- Dependence on environmental parameters (T, S, O_2, hydrostatic pressure)
- Time response of oxygen optodes
- Aanderaa/Sea-Bird oxygen optodes in detail and their sensor drift character

The bio-optical lectures will include a number of topics related to getting acquainted with bio-optical sensors.

Session 4: Introduction to sensor deployment
Instructors: Giorgio Dall'Olmo, Nathan Briggs, Craig Neill and Henry Bittig
This session will describe the plan for how sensor deployment activities will be organized as part of Session 5, on the following day. Participants will be given an assignment to study relevant sensor manuals and come prepared to attempt a self-deployment, under course instructors' supervision and guidance.

Day 2, Tuesday, June 11

Session 5: Sensor deployment: oxygen and bio-optical
Instructors: Henry, Bittig, Craig Neill, Nathan Briggs, Giorgio Dall'Olmo
Participants familiarize themselves with the sensors (oxygen and bio-optical) and deploy them off the quay.

Session 6: Sensors – inside out (Part 2: pH and pCO_2)
Instructors: Phil Bresnahan, Ingunn Skjelvan, Craig Neill, Dariia Atamanchuk
<u>pH</u>
You will learn about the various sensing approaches and types of available technologies to measure pH in situ. The session will focus on potentiometric (ISFET-based) and spectrophotometric (mCP-dye based) pH sensors and their operational principles. Examples of observational networks and ecosystem measurements, which make use of pH technology, will be highlighted.

<u>pCO_2</u>
This session will start with a motivation for measuring CO_2 in the ocean. Then, we will present the theory and methods for CO_2 measurements and provide an overview of several instruments and sensors used to measure pCO_2 in seawater. Further, we will focus on two sensors using infra-red detection of CO_2 and their principles of operation will be presented. Spectrophotometric CO2 determination will briefly be mentioned.

Evening session: Flash (2-min) presentations by participants and lecturers
This will be a special evening session in a relaxed atmosphere (with snacks and drinks in hand) to give us all, course participants and instructors, a chance to properly introduce ourselves to each other. Please prepare a short (max 2 minute!) flash presentation of who you are, and also where you come from, maybe where you went to school, where you work(ed) and maybe who you work with, what brings you to marine science and why you wanted to attend/teach the course - or anything else that you think will help us build a stronger network by the end of the course. This should NOT be a presentation of your research career or your current research project. There will be no possibility to display any slides.

Day 3, Wednesday, June 12

Session 7: Sensor deployment: pH and pCO2
Instructors: Dariia Atamanchuk, Phil Bresnahan, Ingunn Skjelvan and Craig Neill
Participants familiarize themselves with the sensors and deploy them off the pier. This will be a hands-on session, where the participants will be split into groups and work their way through a list of a number of sensors. You will learn how to prepare the sensor for a deployment, and what to consider and check.

Session 8: Interfacing sensors
Instructor: Craig Neill
This lecture will provide practical advice on how to interface sensors with each other and with computers by various methods.

- How to get things to talk to each other
- Maximizing precision and accuracy in analog measurements
- Best practices for cables, connectors etc.
- Bring your questions!

Session 9: Calibration and validation: what are the needs? (Part 1: oxygen and bio-optical)
This session will be composed of three lectures:

- Lecture focused on general perspectives by Craig Neill
- Lecture focused on oxygen sensors by Craig Neill
- Lecture focused on bio-optical sensors by Nathan Briggs/Giorgio Dall'Olmo

Evening session: Optics and oxygen data projects (group work assignment)
The participants will be split into eight groups working on four different datasets. We will provide two optics datasets (chlorophyll-a and backscatter) collected by autonomous platforms that will allow the participants to experience first hand the fun (and difficulties) of analysing real data. Two other assignments will be related to deriving biogeochemical quantities from oxygen data.

Day 4, Thursday, June 13

Session 10: The Carbon system: assessing and controlling measurement uncertainty in estimating the seawater CO_2 system
Instructor: Andrew Dickson
This lecture will cover a variety of topics:

- What is meant by the term "measurement uncertainty"? How is this different from the more traditional terms: "accuracy" and "precision"?
- What is "the seawater CO_2 system"? What measurements are required to provide a complete description of it?

- How do uncertainties in the measured values, of both the seawater sample and of any additional “constants”, used to describe the seawater CO_2 system propagate into resulting uncertainties in any derived values (e.g. aragonite saturation state)?
- How should one decide on appropriate targets for measurement uncertainties when looking to describe the seawater CO_2 system? (I shall briefly summarize the Global Ocean Acidification Observing Network (GOA-ON) approach of defining differing uncertainty goals: “climate” and “weather”, for differing scientific purposes.)
- Having decided on a target uncertainty, how can one estimate the uncertainty for a particular measurement system?
- Having done so, how does one ensure that such an uncertainty is being achieved routinely?

In addition I shall provide a variety of useful background documents that I hope will help you to build upon this necessarily brief introduction.

Session 11: Calibration and validation: what are the needs? (Part 2: pH and pCO_2)

Lecture focused on pH sensors by Phil Bresnahan and Dariia Atamanchuk

The essential components of QA/QC process of in situ pH measurements will be discussed. The recent literature on the topic will be used to exemplify the approach to quality control. Students will learn the inherent errors in multiple measurement techniques.

Lecture focused on pCO_2 sensors by Ingunn Skjelvan

The lecture will discuss the requirements for calibration and validations, e.g. reference systems, reference material, and standard operational procedures. Calibration and validation of some specific CO_2 sensors will be presented, and we will discuss in situ validation by discrete sampling and the quality of calculated CO_2 data.

Session 12: Equilibrator-based surface measurements

Instructors: Gregor Rehder, Craig Neill, Ingunn Skjelvan

This session will combine a theoretical lecture on the principles of equilibrator-based surface measurements, also addressing some of the problems that the approach, despite its maturity, still faces. The lecture will also address the current status and perspective of dissolved gases other than carbon dioxide which can now be continuously measured. The main focus of the session lies on a more practical demonstration and discussion on: operation and maintenance of equilibrator/NDIR systems, tips on installation, and how to spot problems from both hands-on testing and from looking at the data.

Evening session: Optics and oxygen data projects (continued)

Complete analysis, summarise results within each group, compare results with other group working on the same dataset and prepare one presentation for all during Session 17.

Day 5

Session 13: Recovery of oxygen and bio-optical sensors (raw data)
Session 14: Theory of data processing (oxygen and bio-optical)
Session 15: Practicals of data processing (oxygen and bio-optical)
Instructors: Nathan Briggs, Giorgio Dall'Olmo, Henry Bittig, Craig Neill
In these sessions, you will learn the necessary procedures used in sensor recovery, data extraction, and data processing. You will have an opportunity to practice their data processing skills using the datasets collected and obtained from various sensors as well as knowledge gained in the previous sessions.

Day 6

Session 16: How to choose the right sensor depending on your circumstances?
Instructor: Dariia Atamanchuk
This session will address a question of sensor selection according to the goals and conditions of scientific experiment. A number of sensor-based studies will be used as examples highlighting the advantages and limitation of various oceanographic sensors.

Session 17: How to derive meaningful biogeochemical quantities from bio-optical and oxygen sensors?
Instructors: Nathan Briggs, Giorgio Dall'Olmo, Henry Bittig, Craig Neill
Joint presentation of data analysis results from 8 groups working on the data projects, followed by a discussion.
Issues with biofouling in bio-optical measurements also covered in this session.

Day 7, Sunday, June 16

Sessions 18: Recovery of sensors: pH and pCO_2 (raw data)
Session 19: Theory of data processing (pH and pCO_2)
Session 20: Practicals of data processing (pH and pCO_2)
Instructors: Dariia Atamanchuk, Phil Bresnahan, Meike Becker, Craig Neill

In these sessions, you will learn the necessary procedures used in sensor recovery, data extraction, and data processing. You will have an opportunity to practice their data processing skills using the datasets collected and obtained from various sensors as well as knowledge gained in the previous sessions.

Day 8, Monday, June 17

Session 21: Modelling for best observations design; models without data do not work
How can modeling help observationalists, and the other way around; filling gaps in space and time
Instructor: Véronique Garçon
In this session, we will highlight the benefits of using models. The rationale can be: to formalize conceptual ideas, to test hypothesis, to fill gaps in space and time, to make predictions for the future, and/or to quantify feedbacks (i.e. nonlinear responses). A model is a tool. Which types of models can be used for describing physical processes, chemical processes, and biological processes? How can we quantitatively assess models performance? What is meant by validation, evaluation or benchmarking?
Then, we will demonstrate how an ecosystem model may mimic Oxygen Minimum Zones (OMZ) in the Eastern Boundary Upwelling Systems. Interactions between topographic features, coastal atmospheric jets, coastally trapped and internal waves, Ekman transport and submesoscale and mesoscale circulations complicate our ability to represent coastal dynamics in climate models. Quantification of the potential impacts of climate change, and the societal consequences, can be improved with recent advances in physical and biogeochemical observations. We will show how the continuous interactions between models and observations will improve our understanding of the mechanical and thermal forcing of the near-surface ocean in coastal areas, air-sea exchanges, transport and mixing at scale of kilometers or less, and biogeochemical exchanges, interactions, and cycling.

Session 22: How to take care of data?
Instructor: Meike Becker
[Detailed description available soon.]

Session 23: Combining remote sensing and in situ biogeochemical observations
Instructor: Giorgio Dall'Olmo
[Detailed description available soon.]

Session 24: Smart data extrapolation
Instructor: Peter Landschützer
This session will consist of two parts: (I) A short introduction lecture introducing data extrapolation methods used in marine biogeochemistry research. (II) A hands-on computer exercise where participants will directly apply some of the methods. A MATLAB example code will be given to the participants to demonstrate how one can extrapolate sea surface pCO2 measurements in the North Sea domain from 2005-2010 using two artificial neural network algorithms. The exercise will be conducted in groups of 2-3.

Day 9, Tuesday, June 18

Session 25: From surface measurements to ocean-atmosphere fluxes (FluxEngine toolbox)

Instructors: Jamie Shutler, Tom Holding, Ian Ashton

This session will be composed of two parts: i) a lecture given remotely by Jamie Shutler on the state of the art methods, theory and understanding on ocean-atmosphere gas exchange and its importance in quantifying global carbon budgets and guiding policy ii) a practical session led by Tom Holding and Ian Ashton with multiple interactive exercises in how to use of the open-source community developed FluxEngine toolbox for calculating ocean-atmosphere gas fluxes. This will include calculations and methods using solely in situ data (e.g. collected from fixed stations, drifting buoys or research cruises) and those using combinations of satellite Earth observation, model and in situ data. Example analyses for global, regional, fixed station and cruise tracks will be included. Participants will work through complete case studies from initial data processing to calculating ocean-atmosphere gas fluxes and visualising the results.

Session 26: All I always wanted to know about sensors

Hands-on Question & Answer session with course instructors as expert users and manufacturers (Pro-Oceanus, RBR). Multiple types of sensors will be presented and discussed for each parameter.

Session 27: Short presentations by sponsors and manufacturers

The main sponsors of the Summer School will briefly present the mission of their organization / projects (IOCCP, BONUS INTEGRAL, ICOS OTC), including the motivation to host the event. Afterwards, room is given to the representatives of the manufacturers to present their company and relevant products.

Day 10, Wednesday, 19 June

Session 28: Emerging technologies

Instructors: Doug Connelly and Véronique Garçon

This session will consist of 2 parts: (I) Doug's talk will focus on emerging technologies in the realm of in situ sensing, including those around genomics and the recently defined biological EOV's. Doug will cover some of the work done in SenseOCEAN and the other Oceans of Tomorrow projects leading into the talk by Veronique. (II) An introduction to electrochemistry as a powerful tool to develop in situ, autonomous sensors to detect nutrients in seawater. Veronique will first describe briefly the SenseOCEAN project and some background on electrochemical methods. Veronique will show the increase in technology readiness level by going from principles to laboratory prototypes and to in situ nutrient sensors. Nitrates, silicates and phosphates behave differently since nitrate are electroactive species but

silicate and phosphate are electro-inactive. First field deployments and future roads of development will be presented.

Session 29: Biofouling: issues and solutions
Combined lecture from several experts + open discussion. Participants are encouraged to bring their own examples of bio-fouling issues if available (e.g. prepare 1 slide ahead of the session).

Session 30: Ocean Best Practices (OBP) Initiative and Repository
Instructors: Maciej Telszewski and Artur Palacz
This session will introduce the Ocean Best Practices Initiative and the currently developed repository as a valuable resource for the community of marine biogeochemistry observers. An introductory presentation will be followed by a demonstration of selected functionalities of the new repository and a short assignment for participants.