
# ESA Advance Ocean Training Course 2025

# Shore-based Course

## Student Handbook

(Version 2.3, 25th October 2024)

# Change Log

Title: Advanced Ocean Synergy Training Course #OTC25 Shore-based Course Student Handbook

| Reason for change | Issue. | Revision | Date |
|---|---|---|---|
| Version 0.1 draft | 0 | 1 | 31/07/2024 |
| Updated content | 0 | 2 | 24/09/2024 |
| Updated timetable | 0 | 3 | 1/10/2024 |
| Version 1.0 (consolidated) | 1 | 0 | 10/10/2024 |
| Updated timetable and completed most of Biographies and Lecture abstracts | 2 | 0 | 14/10/2024 |
| Complete version for initial dissemination | 2 | 1 | 17/10/2024 |
| Updated timings for ship embarkation disembarkation – Mahon is now a port call on 1/06/2025 | 2 | 2 | 25/10/2024 |
| Changed timetable for. E. Boss Lecture | 2 | 3 | 25/10/2024 |

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# 1. WELCOME TO THE ESA #OTC25 TRAINING COURSE

Congratulations on your successful application and Welcome to the European Space Agency Advanced Training on Ocean Synergy Remote Sensing #OTC25! This is the eighth ESA Ocean Training Course of the series devoted to you - the next generation of Earth Observation (EO) scientists.

Inside this document you will find practical arrangements for the #OTC25 Shore-based course. A separate and more detailed course handbook is being finalised for the At Sea part of the course for those who will participate.

Our aim is to help you to exploit data from ESA and operational EO Missions for science and applications development. Ocean and atmosphere dynamic processes define the surface expressions imprinted on the sea surface or in the atmosphere that we can measure from space. In order to extract scientific knowledge from satellite data, it is fundamental to understand the processes that define the signals we can measure. This is at the very heart of the #OTC25 which has the following course aim:

***To understand and interpret the ocean signatures that are measured from complementary satellite instruments in space by studying the sensor physics used to measure ocean signals and the fundamental ocean and atmosphere processes that define those signals.***

During the course, we will use the following general themes to help organise our training:

- Upper Ocean Dynamics, Mesoscale and Sub-mesoscale Structures
- Ocean bio-geo-chemistry
- Marine Meteorology and Air-Sea interaction

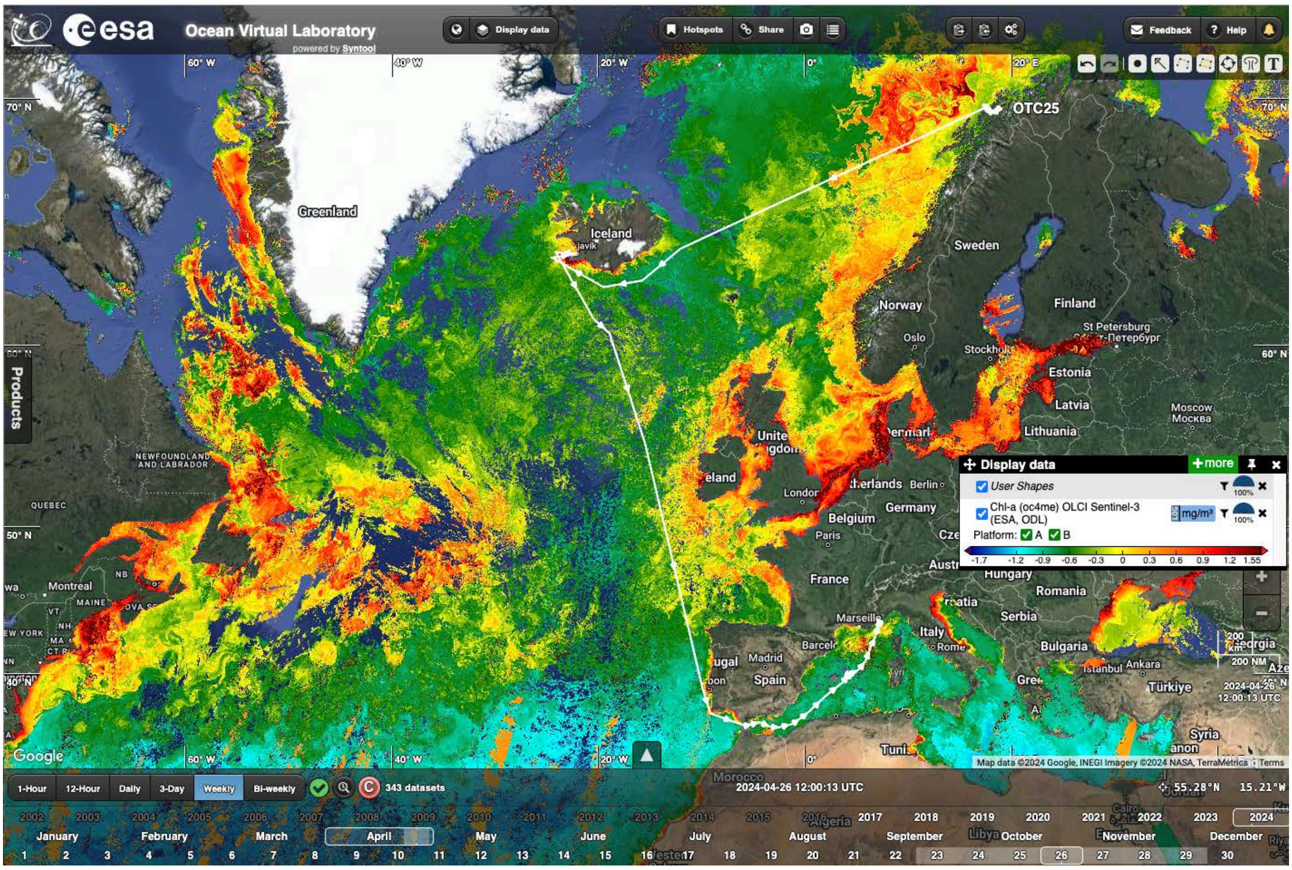

We will assign you to one of the three groups listed above but you are free to team up in sub-groups under these themes. We will try to develop a multi-disciplinary team within each group. Please inform craig.donlon@esa.int if you would like to be moved to a different thematic group.

Working together informally in groups is an excellent way to interact and learn from each other. Together with the lecturers of the course we will run informal group sessions that are designed to help consolidate your understanding of what you have learned during the course.

The best place to do this is on the ocean surface itself which is why the #OTC25 Training Course consists of two mandatory parts: A ship based component where measurements are made at sea to support Student projects together with group work and lectures aboard the ship.  Prior to this, a shore-based component will be run on-line that is focussed on explaining ocean earth observation techniques with a dedicated focus on the oceanography from space along the track to be followed during the at sea component.

## 1.1. OTC25 SHIP-BASED COMPONENT

The OTC25 ship-based component will take place aboard the tall ship *Statsraad Lehmkuhl* (https://lehmkuhl.no/en/) during the One Ocean expedition from Tromsø, Norway, to Nice, France, via Reykjavik, Iceland (see draft voyage track here).




Indicative route of the Tall Ship Statsraad Lehmkuhl during the #OTC25 voyage.  The map shows a 2-week composite of Chlorophyll-a derived from Sentinel-3 Ocean and Land Colour Instrument (OLCI, https://sentiwiki.copernicus.eu/web/s3-olci-instrument) using the OC4ME algorithm (for a review of different algorithms see https://www.sciencedirect.com/science/article/pii/S0034425716304515).

| | |
|---|---|
| Embark ship in Tromsø, Norway: | 21 April 2025 |
| Leg1: 14 days at sea, 1250 nm. Time allocated includes 4 hours per CTD assuming mean SOG of 4.8kt | |
| Depart Tromsø, Norway: | 22 April 2025 |
| Arrive Reykjavik, Iceland: | 5-May 2025 |
| 3 days in Reykjavik | |
| Leg2: 29 days at sea, 2800 nm. Time allocated includes 4 hours per CTD assuming mean SOG of 5.0kt and short stop outside Mahon for VIP pickup | |
| Embark ship in Reykjavik, Iceland: | 7 May 2025 |
| Depart Reykjavik, Iceland: | 8 May 2025 |
| Pickup Mahon (no port call): | 1 June 2025 |
| Arrive Nice, France: | 3 June 2025 |
| UNOC Events in Nice | 3-6 June 2025 |
| Disembark Nice, France: | 6 June 2025 |


Put these dates into your agenda and block out your time – start planning your trip to Tromsø, Norway, your return from Nice, France (or Reykjavik, Iceland), and your science plans!


Students – ie. you! - must arrange their own travel to join the ship in Tromsø on or before 21st April 2025 and their return journey from Nice, France after 6th June 2025. ESA will cover the cost of your accommodation and meals aboard the Ship. We suggest you reserve your flights and any accommodation well in advance to minimise your costs.

During this part of the One Ocean Expedition we will depart Tromsø on 22nd April 2025 to sail 6200 nm in about 43 days arriving in Nice, France on 3rd June 2025 as part of the opening events for the United Nations Ocean Conference 2025 (https://sdgs.un.org/conferences/ocean2025). More information about being on board the ship can be found at https://lehmkuhl.no/en/life-on-board/. The ESA Ocean Synergy Training Course 2025 is part of the One Ocean Expedition, which is a scientific and educational voyage around the Northern Hemisphere oceans, aboard the tall ship Statsraad Lehmkuhl, in 2025-2026, please refer to the Statsraad Lehmkuhl handbook, there, you can discover more about life on board, the ship, and the art of sailing a Tall ship – it needs all of us to do this!


**Read the Handbook for sail trainees on board Statsraad Lehmkuh available at** https://oceantrainingcourse2025.esa.int/wp-content/uploads/2024/06/English_Handbook_S_Lehmkuhl_LQ.pdf

Accommodation on board the ship is in mixed dormitory rooms sleeping in a hammock. You will be expected to participate in the operation of the ship as part of the ship's crew working on a 4-hour on, 8-hour off watch system every day:

00:00 – 04:00 and 12:00 – 16:00 Red watch

04:00 – 08:00 and 16:00 – 20:00 White watch

08:00 – 12:00 and 20:00 – 00:00 Blue watch

Scientific work will be conducted as part of the Science Watch and in the time between formal watches. Lectures will be arranged within the working framework of the ship.

Advanced training activities in satellite oceanography will be run aboard the ship with a focus toward supporting student personal science activities that will be developed throughout the on-line training and explored further aboard the ship. You will be working side-by-side with your lecture team allowing unprecedented access to a wealth of experience and technical knowledge allowing you to get the most out of your time at sea.


| Quantity | Sensor | Measurements at sea | Description | Link / specs | Installation |
|---|---|---|---|---|---|
| **Permanent equipment - the backbone instrumentation** | | | | | |
| 2 | Smart sensor | Continuous | WS700-UMB | https://www.lufft.com/products/compact-weather-sensors-293/ws700-umb-sma | Mast |
| 2 | Radar Precipitation Sensor | Continuous | WS100 | https://www.lufft.com/products/precipitation-sensors-287/ws100-radar-precipita | Mast |
| 2 | IR sensor for SST skin temperature measurements | Continuous | Apogee SI-421-SS | https://www.scaledinstruments.com/shop/apogee-instruments/infrared-radiomet | Mast |
| 1 | Carousel (sensors, watersamplers) | Stations | SBE 32SC SUB COMPACT CAROUSEL - 12x2.5l | https://havforskningsinstituttet.sharepoint.com/:x:/r/teams/OneOcean2/Shared% | CTD Carousel |
| 1 | Winch for carousel | Stations | EIVA OceanEnviro | https://www.eiva.com/products/hardware/oceanenviro-winches | Deck |
| 1 | CTD - carousel | Stations | Seabird SBE19plus V2 | https://www.seabird.com/sbe-19plus-v2-seacat-profiler-ctd/product?id=607614 | CTD Carousel |
| 1 | Dissolved oxygen - carousel | Stations | SBE43 DO | https://www.seabird.com/sbe-43-dissolved-oxygen-sensor/product?id=6076246 | CTD Carousel |
| 1 | ChlA/turbidity/backscatter - carousel | Stations | CHL-a & TURBIDITY ECO-FLNTU | https://www.seabird.com/eco-flntu/product?id=60762467722 | CTD Carousel |
| 1 | PAR - carousel | Stations | SATPAR PAR-LOG ICSW, | https://www.seabird.com/photosynthetically-active-radiation-par-sensor/product | CTD Carousel |
| 1 | PAR - carousel | Stations | SATPAR SURFACE/REFERENCE PAR | https://www.seabird.com/photosynthetically-active-radiation-par-sensor/product | CTD Carousel |
| 1 | pH - carousel | Stations | SBE18 pH | https://www.seabird.com/ph-sensors/sbe-18-ph-sensor/family?productCategory | CTD Carousel |
| 1 | ADCP - 300 kHz | Continuous | Kongsberg CP300 | https://www.kongsberg.com/discovery/ocean-science/ocean-science-transducers | Hull mounted |
| 1 | ADCP - 75 kHz | Continuous | Teledyne RDI Ocean Surveyor ADCP (75kHz) | https://www.teledynemarine.com/brands/rdi/ocean-surveyor-adcp | Hull mounted |
| 3 | Hydrophone hull mounted | Continuous | Ocean Sonics icListen HF | https://oceansonics.com/iclisten-hf-hydrophone/ | Hull mounted |
| 1 | SooGuard - Ferrybox | Continuous | AADI SOOGUARD Ferrybox system | https://www.aanderaa.com/media/pdfs/b188-sooguard-ferry-box-system.pdf | Water intake / below deck |
| 1 | *Conductivity, temperature - Ferrybox* | *Continuous* | *AADI 4319B* | https://www.aanderaa.com/media/pdfs/TD263-Condcutivity-sensor-4319.pdf | *Water intake / below deck* |
| 1 | *O2 - Ferrybox* | *Continuous* | *AADI 4835* | https://www.aanderaa.com/oxygen-sensors | *Water intake / below deck* |
| 1 | *Turbidity - Ferrybox* | *Continuous* | *AADI 4112* | https://www.aanderaa.com/turbidity-sensor | *Water intake / below deck* |
| 1 | *ChlA - Ferrybox* | *Continuous* | *Turner Designs Cyclops* | https://www.turnerdesigns.com/cyclops-7f-submersible-fluorometer | *Water intake / below deck* |
| 1 | *Phycoerythrin - Ferrybox* | *Continuous* | | | *Water intake / below deck* |
| 1 | Scientific Echosounder EK80 | Continuous | Kongsberg wideband scientific echosounder (WBT) | https://www.kongsberg.com/discovery/ocean-science/ek-family/ek80/ | Hull mounted / blister |
| 1 | *Kongsberg ES38/200 Combi C echosounder transducer* | *Continuous* | *38 (split-beam) and 200 kHz (single-beam) echosounder transducers* | https://www.kongsberg.com/discovery/ocean-science/ocean-science-transducers | Hull mounted / blister |
| 1 | *Kongsberg ES120-7C echosounder transducer* | *Continuous* | *120 kHz split-beam echosounder transducer* | https://www.kongsberg.com/discovery/fish-finding/fishery-split-beam-transducer | Hull mounted / blister |
| 1 | eDNA filtration | Manual samples | Manual water samples water intake + towed water sampler ("torpedo") | - | Water intake / lab |
| 1 | eDNA extraction | Manual samples | Biomeme Franklin qPCR, Biomeme M1 Cartrigde | https://shop.biomeme.com/franklin-real-time-pcr-thermocycler/ | |
| 1 | Microplastics filtration/analysis | Manual samples | Lab / water intake + particle sizes, number (more info comming) | Comming | Water intake / lab |
| 1 | CTD | At stations | Additional CTD / high res 100m (Xylem Castaway) | https://www.xylem.com/en-us/products--services/analytical-instruments-and-eq | Lowered |
| 2 | Fishing equipment | Manual samples | Specs | | Lowered |
| 1 | Net sampling | Manual samples | WP2 plankton net, mesh size of 180 micrometer | | Lowered |
| 3 | SeaAwarenes camera | Continuous | 2xKCC100, 1xKCC 200n | https://www.kongsberg.com/discovery/navigation-positioning/kongsberg-camera | Mast |
| 1 | PAR | Continuous | Quantum SQ-522 | https://www.apogeeinstruments.com/content/SQ-522.pdf | Mast |
| 1 | Ocean model | Continuous (downloaded data) | Mercator/Blue Insight (data downloaded and made accessible to crew and scientists | | - |
| 2 | TorpedDNA | Manual samples | eDNA sampler | | Towed |
| 2 | Freezers | Continous | Specs | | - |
| 1 | Data management and event logging | Continuous | KD Blue Insight for data storage, event logging, transmission of data, acces to data ombord | | - |

Scientific equipment aboard the Statsraad Lehmkuhl (Additional equipment may be available from the lecture team and you can propose to bring your own instruments (subject to agreement with the ship). If you wish to bring your own instruments, please contact craig.donlon@esa.int as soon as possible.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Activities aboard the ship, by default, are tailored to the regional characteristics of the Norwegian Sea, Northeast Atlantic Ocean and Mediterranean Sea. That's quite a range of water masses! During the voyage, you will collect *in situ* observations and use these together with satellite data and ocean model outputs to interpret the ocean state, monitor the bio-geo-chemistry of the ocean, validate satellite and model data amongst other activities - and you shall conduct your own ocean science research following your own proposed research plan. At the heart of the OTC25 we know that being at sea is the best place to understand the origin of the signals we measure from space!

A dedicated course handbook will be prepared to cover the activities aboard the Statsraad Lehmkuhl in early 2025. In the meantime, we ask you to prepare and send a personal ocean science research plan (4 pages maximum) to the course Leaders by January 10th 2025 so that we can organise our activities at sea around your needs. As several people may have similar interests and wish to work together, a small group research plan can also be prepared.


**Prepare and send your personal/small group ocean science research plan explaining what you intend to do aboard the Statsraad Lehmkuhl during the at sea course detailing: science questions you will focus on, what measurements and equipment you will need (or plan to bring to the ship), the data processing you plan to conduct, and the outcomes you expect to achieve. Maximum of 4 pages sent by email to the course Leaders by January 10th 2025.**

## 1.2. OTC25 SHORE-BASED ONLINE COMPONENT

Your lecturers have planned an exciting and stimulating program of activities for our time together focusing on preparation for the ship-based activity. These are designed to develop your skills in ocean remote sensing and promote the use of different data sets in synergy to address a broad range of issues from scientific research to operational applications. Our satellite instruments have wonderful "eyes" in space that can work together to get a more useful view of our planet Earth. Through a combination of formal and interactive practical sessions and group work, our lecturers will then build up your knowledge starting from the big picture topics, working through theoretical measurement principles of different satellite instruments and corresponding algorithm retrieval methods, interspersed with hands-on practical work that will consolidate your understanding.

The shore-based Advanced Training on Ocean Synergy Remote Sensing course is designed to help you work with increasingly varying but complementary satellite data sets to study the ocean. The OTC25 shore-based course consists of 19 two hour modules that are run online via Webex connections once per week for a duration of 2 hours each (Tuesday evenings 16:30-18:30 ).

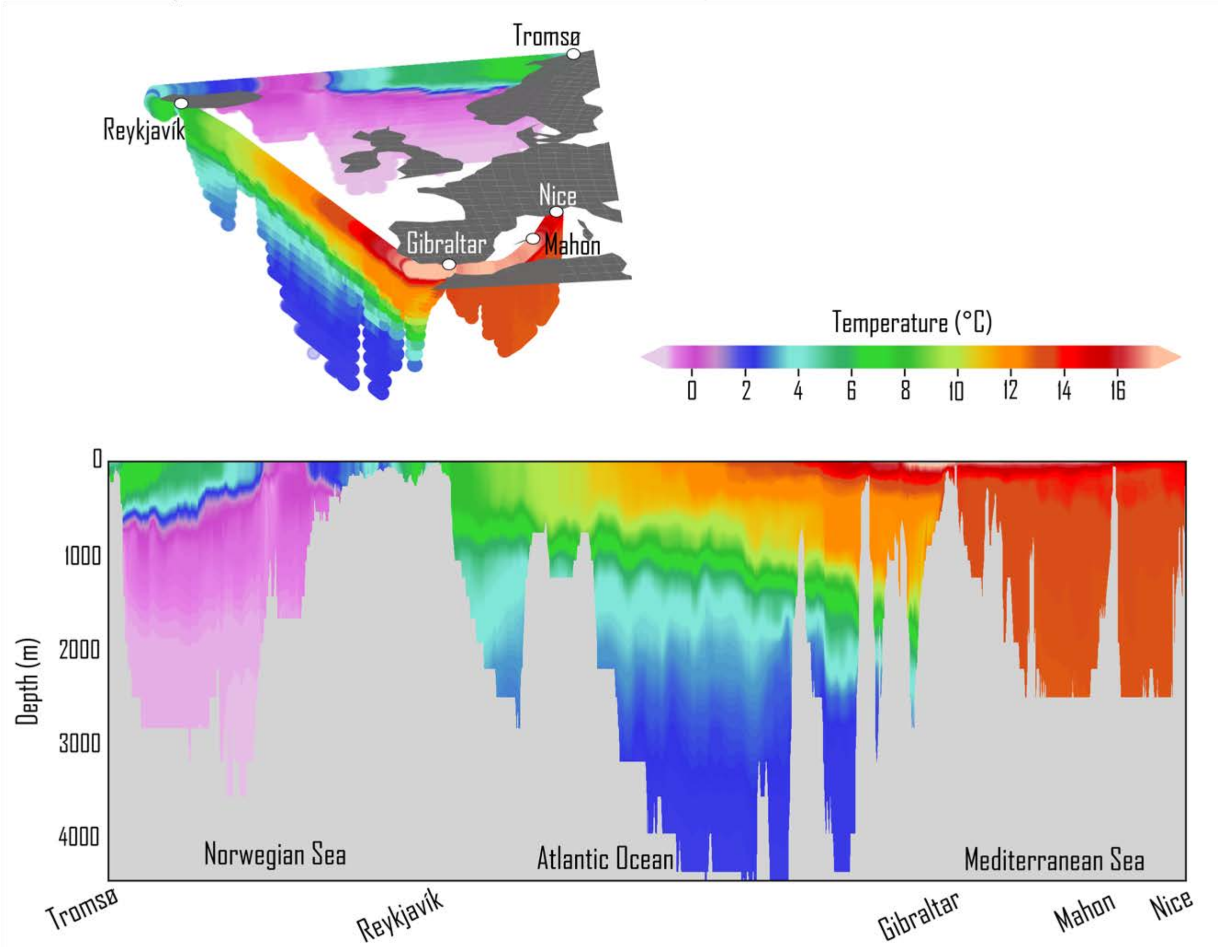

Please note that it is **mandatory** to register and attend all of the Shore-based course Modules to maintain your place abord the tall ship Statsraad Lehmkuhl in 2025. Please inform the Course coordinators if you cannot attend a session explaining why. Each module will be recorded and made available online afterwards, so students are expected to catch up with any missed lectures. Registration is via the link in the timetable below – we will record who is in attendance.

Each module will explain a different Earth Observation satellite measurement: how they work, how different instruments measure different parameters, and how we can apply derived data in different ways for ocean science applications. **The shore-based course will focus on a Virtual Voyage of the expected ship route in 2025.**

The course will build up knowledge and know-how over the weeks using a combination of formal lectures and interactive lectures focussed on the oceans from space along the voyage track of the *Statsraad Lehmkuhl*. You will review what satellites are used for ocean science, how the payload instruments work, be exposed to different synergy topics and how we use satellite data in synergy, hands-on use of complementary and exciting data sets using modern tools so that that you can interact with satellite data yourself. We will also cover in situ Fiducial Reference Measurement techniques, why they are so important and what you can expect during the ship based component of the course. It will be a full, busy and fun course!

A broad range of disciplines will be covered including upper ocean dynamics, air-sea interaction, coupling of ocean physics to biogeochemistry, marine biology, ocean acidification, ocean modelling, in situ measurements, and climate change.

Interactive lectures will focus on specific areas of ocean synergy and will use software tools that are available free of charge for students to use after the course. Useful software tools will be introduced and explained enabling you to use these as part of your personal research during the at sea course.




Vertical distribution of potential temperature (theta) along the planned track of the Statsraad Lehmkuhl during the #OTC25 voyage from Mercator global 1/12° analysis and forecast operational run highlighting the very different vertical stratification across the Norwegian sea, the Northeast Atlantic Ocean and the Mediterranean Sea (Credit Mercator Ocean/CMCES). See https://tinyurl.com/2zb76eyu for more details.

In addition, informal group work will enable students to bring to the course their ideas and needs for open informal discussion.

During the shore-based course we will:

- Train the next generation of Earth Observation Ocean Scientists,
- Explain the theoretical principles and application of Ocean Colour Radiometry, Infrared and Passive Microwave Radiometry, Biogeochemistry, Sea Surface Temperature, Sea Surface Salinity retrievals, Synthetic Aperture Radar and Radar Altimetry and Gravimetry;
- Introduce different satellites and their payload instruments.
- Explore data through hands-on exercises using SAR, Optical, Infrared, Passive Microwave, and Altimeter data, tools/toolboxes and methods for the exploitation of EO satellite data in synergy over the ocean.
- Stimulate and support the exploitation of the ESA Earth Explorer and Copernicus Sentinel Missions.

- Explain in situ measurement techniques and the importance of Fiducial Reference Measurements (FRM),
- Apply knowledge of satellite measurements in synergy to understand *the character and dynamics of the ocean along the* voyage track of the *Statsraad Lehmkuhl.*

As an example, you can access all of the ESA 2023 Training course materials and recorded lectures here.

## 1.3. YOUR COMMITMENT AND RESPONSIBILITY TO THE OTC25

**You** have been chosen from a large number of applications and we expect you to be fully committed to making the OTC25 a special and scientifically relevant event. We have worked hard to prepare the course over the last 18 months and we want to enjoy the scientific discovery that comes with every voyage at sea just as much as you. As such, your selection comes with our expectation that you will fully engage and participate in all the activities we can offer.

We expect you to arrange your own travel to and from the ship and to come prepared with the right clothing for the Voyage and a "Dare to Dream" scientific mindset. The course is what you choose to make of it – including preparation of journal articles.


You will be asked to prepare a personal scientific voyage report (perhaps in the form of a draft journal article) based on your personal studies. This should explain the scientific work completed during the #OTC25 using the data collected aboard the ship and from satellite measurements. <u>This is due by 1st November 2025.</u>


In addition, a group report must be prepared together with your group colleagues that explains the scientific work of the group and the outcomes/conclusions achieved. <u>This is due by 20th June 2025.</u>

<u>These two deliveries are mandatory to be granted the ESA Training Course Certificate.</u>

## 1.4. GET READY – HERE WE GO!

We are here for you and, we take your needs and scientific curiosity seriously. Our course differs substantially from other ocean training courses because it builds on feedback from student and lecturer synergies, time at sea and a desire to discover more about our ocean.

As course coordinators, we want to emphasize that our motto is "*Laborare et laborare ludere*" (work hard and play hard!) – we want your course to be a time where you learn a lot, meet new people and create your network of EO peers, and have some fun with Earth observation! Our ambition is simple: Oceanography from Space is just a wonderful world and an exciting future career choice – we hope that by the end of the #OTC25 you will agree with us! And in all things, we must have fun while working together!

We hope that #OTC25 will be just what you need to develop your career studying the Oceans from Space. We are looking forward to meeting you on-line later this year and we wish you a safe journey to Tromsø where we meet you for a great scientific adventure aboard the majestic tall ship *Statsraad Lehmkuhl*!

*Craig Donlon*

*Fabrice Collard*

*Johnny A. Johannessen*

*Haakon Vatle*

# 2. CONTACT DETAILS

The points of contact for the #OTC25 course are:

**ESA Course Leader:**

Dr. Craig Donlon
m: Craig.Donlon@esa.int
t: +31 0627 013 244

**ODL Course Leader:**

Dr Fabrice Collard
m: fabrice.collard@oceandatalab.com
t: +33 662 406 873

**NANSEN Centre Leader:**

Prof. Johnny A. Johannesen
m: Johnny.Johannessen@nersc.no
t: +47 932 49 414

**Statsraad Lehmkuhl Leader:**

Haakon Vattle
m: haakon.vatle@lehmkuhl.no
t: +47 975 37 984

**OTC25 Scientific Student Liaison Officer aboard the ship**

Maryke Bezuidenhout

m: marykebez@gmail.com

t: +27 82 771 0397 and whatsapp.

Maryke is available 24/7 for any issue you have or to talk to about anything in full confidence while on board the ship. She is there to support you whatever the issue.

## Course coordinators:

Catherine Downy
m: Catherine.downy@nersc.no

Sabrina Lodadio
m: Sabrina.Lodadio@ext.esa.int

## Lecture Team

Biographies of your lecture team are provided in Section 6 of this document.

## 2.1. #OTC25 SOCIAL MEDIA

Social media is a way of life for us all and let´s use it to celebrate the #OTC25 course! Fun photos are great, but we'd ask you to remain professional please! The following social media channels are associated with the OTC25:

- **#OTC25 website**: https://oceantrainingcourse2025.esa.int/
- X: (#OTC25) feel free to promote the course and your views via X. Our Social Media Coordinators will help propel your Tweets up the chain.
- WhatsApp Students group: https://chat.whatsapp.com/ENBuvB3cPKvDU4hRWKYivf
- #OTC25 Email List: Ocean.Training@esa.int


**House Rules for the WhatsApp and Email List:** We will use these lists to keep everyone updated about both parts of the course, online and at-sea. They can be used as forum for sending questions to each other and all the lecturers from the online course are included in the list. Please be aware that this list contains over 100 people so consider your post carefully before sending. Only send posts that will be of relevance to everyone – by this we mean we would like you to send any scientific questions about the content of the course but keep any polite replies direct to the sender (e.g., saying thank you for information received). Also, be careful about sending any personal information out on the email list.

## 2.2. #OTC25 SHORE-BASED PRACTICAL ARRANGEMENTS

Running large classes via Webex doesn't have to be a challenge – but it can be a nightmare if we don't all work together. Please try to follow the guidelines below so that we can all experience a good class and minimize down time for you and everyone else!

1. **You will need a computer that you have download rights for, plus a good internet connection**.

2. The Shore based course will be run ***every Tuesday afternoon via Webex links between 16:30-18:30 CET- Central European Time (or CEST Central European Summer Time after 31st March 2025).*** Each week the same format will be used which combines formal lectures with hands-on practical sessions that are run by you on your own computer.

3. In addition, there will be extra lectures on Monday 18th November 2024 and Monday 27th January 2025. A longer session starting at 14:00 on 15th April 2025 will clarify final arrangements for joining the ship!

4. Please try to ***connect in good time*** for the module start – 5 minutes or so before we are due to start is good (e.g.16:25) – since this will give you time to ensure your audio and visual equipment is working well.

5. Please ***read the Webex best practices guidelines*** which are available at: https://www.webex.com/content/dam/webex/eopi/assets/WebexMeetings_BestPractices.pdf

6. ***Download and install the Webex Meetings application*** – the Webex Meeting application is the fastest way to join a meeting. Download Webex at https://www.webex.com/downloads.html

7. Please use the links in the next section to ***Register for Each course Module*** – once registered an email will be sent to you with details of how to join the module Webex. You must register for each module separately.

https://esait.webex.com/esait/j.php?RGID=r7fee361a32b23a1f983eed2c93aa4f19=

8. During the Module Webex, please ***keep your microphone turned off*** so that you are not the one causing a howling feedback for everyone! We suggest that you ***use a headset*** which greatly helps in this respect.

9. Update your calendar with all of the scheduled Sessions with reminders so that you don't forget! ***Please note that it is mandatory to attend all of the Shore-based course Modules to secure a place abord the tall ship Statsraad Lehmkuhl in January 2025.***

# 3. SHOREBASED COURSE SCHEDULE AT A GLANCE

| Duration | | 16:30-16:50 | 16:50-17:10 | 20' | 17:30-17:50 | 17:50-18:15 | 15' | Registration link |
|---|---|---|---|---|---|---|---|---|
| 12th Nov 2024 | General Introduction<br>Groups | 5.1 Welcome and Introduction to the Training Course and what we expect from you<br>Peter Thompson (UN Special Envoy for the Ocean, Dr Craig Donlon (ESA) and Dr Fabrice Collard (ODL) | 5.2 Student projects and group work – working together<br>Prof. Johnny A. Johannesen (NERSC) and Dr Craig Donlon (ESA) | | 5.3 Round Table Introduction from Lecturer Team: Who are you and what do you want to get out of the course?<br>Dr Craig Donlon (ESA) | 5.3 Round Table Introduction from Students: Who are you and what do you want to get out of the course?<br>Dr Craig Donlon (ESA) | | https://esait.webex.com/weblink/register/r6d56f5671e51cabadb7670d120d7e1eb |
| 18th Nov 2024 | Preparing Computer Tools | 5.4 OTC25 Student installation of computer tools and tutorial "clinic" to troubleshoot<br>Lucille Gaultier (ODL) and OTC25 Team | | | 5.4 OTC25 Student installation of computer tools and tutorial "clinic" to troubleshoot<br>Lucille Gaultier (ODL) and OTC25 Team | | | https://esait.webex.com/weblink/register/reac6d13aeefaed5c8468b400a6ca0289 |
| 19th Nov 2024 | Oceanography of the Voyage | 5.5 The One Ocean Expedition and ESA OTC25<br>Haakon Vattle (Statsraad Lehmkuhl Foundation) | 5.6 Norwegian Sea from Space and below<br>Prof. Johnny Johannessen (NERSC) | | 5.7 Northeast Atlantic Ocean from space and below<br>Dr Craig Donlon (ESA) | 5.8 Mediterranean Sea from Space and below<br>Dr Fabrice Collard (ODL | | https://esait.webex.com/weblink/register/r0a4d4a56fa74e19ae0ef903199a8cd53 |
| 26th Nov 2024 | SEAScope and OVL Portal | 5.9 Introduction to OVL Portal<br>Dr Lucile Gaultier, Dr Fabrice Collard (ODL) and Ziad El Khoury Hanna (ODL) | | | 5.10 Introduction to SEAScope Visualisation and Analyses tool<br>Dr Lucile Gaultier (ODL), Dr Fabrice Collard (ODL) | | | https://esait.webex.com/weblink/register/r8fef78b5c7c73f27f53988cdc444c0cc |
| 3rd Dec 2024 | Mesoscale and sub-mesoscale Structures (Thermal imaging) | 5.11 Thermal Imaging of the Ocean from Space<br>Dr. Gary Corlett (EUMETSAT) | 5.12 Thermal Imaging of the Ocean from Space (interactive session)<br>Dr. Gary Corlett and Dr Ben Loveday (EUMETSAT) | | 5.12 Selecting, exploring and validating sea surface temperature products<br>Dr. Gary Corlett and Dr. Ben Loveday (EUMETSAT) | 5.12 Selecting, exploring and validating sea surface temperature products (interactive session)<br>Dr. Ben Loveday (EUMETSAT) | | https://esait.webex.com/weblink/register/r4888cad8b1a645fddb6ae8df3042043a |

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| 10th Dec 2024 | Measuring SST and Salinity from Microwave Radiometers | 5.13 Microwave Radiometry of the Ocean from Space<br><br>Dr. Craig Donlon (ESA) | 5.14 SST/SSS/ and extreme wind observations from Microwave Radiometers<br><br>Dr. Nicolas Reul (IFREMER) | | 5.14 SST/SSS/wind observations from Satellite Microwave Radiometers during the OTC25 Voyage<br><br>Dr. Nicolas Reul (IFREMER) | | | https://esait.webex.com/weblink/register/r5c3f29cedc1138941cd1d395c82d4b12 |
| 17th Dec 2024 | Mesoscale and sub-mesoscale Structures (OCR imaging) | 5.15 Ocean Colour Radiometry (OCR) of the ocean from space<br><br>Dr. Astrid Bracher (AWI) and Dr Hayley Evers-King (EUMETSAT) | 5.16 Deriving geophysical information from the ocean colour signal<br><br>Dr Hayley Evers-King (EUMETSAT) and Dr. Astrid Bracher (AWI) | | 5.17 Regional Ocean colour applications<br><br>Dr Hayley Evers-King (EUMETSAT) and Dr. Astrid Bracher (AWI) | 5.18 In situ approaches to complement Satellite ocean colour in Marine Microbial Research<br><br>Dr Kat Morissey (Univ. Capetown) | | https://esait.webex.com/weblink/register/r5c3f29cedc1138941cd1d395c82d4b12 |
| 7th Jan 2025 | Looking into the ocean using Ocean Models | 5.19 Ocean Forecasting: models, data, access and applications<br><br>Dr Karina von Schuckmann (Mercator Ocean) | | | 5.19 Ocean Forecasting: models, data, access and applications<br><br>Dr Karina von Schuckmann (Mercator Ocean) | | | https://esait.webex.com/esait/j.php?MTID=mc96f3226e0188e5ffede62db425b6af3 |
| 14th Jan 2025 | Marine biology from Space | 5.20 Making OTC25 Measurements at Sea<br><br>OTC25 Team | | | 5.20 Making OTC25 Measurements at Sea<br><br>OTC25 Team | | | https://esait.webex.com/weblink/register/rc11b457a119bafbe5fdc204e7c3cc002 |
| 21st Jan 2025 | Making Measurements at sea | 5.21 Ocean Instruments aboard the Statsraad Lehmkuhl<br><br>Geir Pendersen (Institute of Marine Research, Norway) | | | 5.21 Ocean Instruments aboard the Statsraad Lehmkuhl<br><br>Geir Pendersen (Institute of Marine Research, Norway) | | | https://esait.webex.com/weblink/register/r115a1e91b043c4961e92a7ec9c675cce |
| 27th Jan 2025 | Making Measurements at sea | 5.22 Relationship between ocean matter and its optical properties.<br><br>Dr. Emmanuel Boss (University of Maine, USA) | | | 5.23 How we measure the optical properties of the material in the ocean.<br><br>Dr. Emmanuel Boss (University of Maine, USA) | | | https://esait.webex.com/weblink/register/rb4f6976205eef3787e262ff05a6b79f7 |

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| 28th Jan 2025 | Marine Acoustics and Gravimetry | 5.24 Remote Sensing in the Ocean: Basic Principles and Applications of Underwater Acoustic measurements<br>**Roger Haagmans** | | | 5.25 Gravity and the Ocean<br>**Roger Haagmans** | | | https://esait.webex.com/weblink/register/r6b98eee84c9bc0cf94bbf31239792dd8 |
| 4th Feb 2025 | Satellite Altimetry | 5.26 Satellite Altimetry of the Oceans from space<br>**Dr. Alejandro Egido (ESA)** | | | 5.27 Estimates of Ocean Circulation from Satellite Altimetry<br>**Dr. Marie Helene Rio (ESA)** | 5.28 Jupiter notebook on geostrophic surface current estimation from altimeter sea surface height<br>**Dr. Lucile Gaultier (ODL)** | | https://esait.webex.com/weblink/register/rce18c2f7c462d9b190570af4e69e1626 |
| 11th Feb 2025 | Ocean Circulation from Synergy (altimeters) | 5.29 Regional sea-level variability and budget: a focus on the Nordic high latitudes<br>**Dr Antonio Bonaduce (NERSC)** | 5.30 Advanced techniques for mapping sea surface height (SSH) from space<br>**Florian Le Guillou (DATLAS, France)** | | 5.31 Satellite Altimetry in synergy with other measurements<br>**Dr. Marie Helene Rio (ESA)** | 5.32 Upper dynamic synergies synoptic chart analysis and velocity products intercomparison<br>**Dr. Lucile Gaultier (ODL)** | | https://esait.webex.com/weblink/register/rfe44d9d817b8df67dc7ba68ed34b27e4 |
| 18th Feb 2025 | Wind and wave current measurements from Space (Synthetic Aperture Radar) | 5.33 Estimating Sea State from Space using Synthetic Aperture Radar (SAR)<br>**Dr Bertrand Chapron (IFREMER) and Dr Fabrice Collard (ODL)** | 5.34 Directional Wave Spectrum from space<br>**Dr Bertrand Chapron (IFREMER) and Dr Fabrice Collard (ODL)** | | 5.35 Direct observations of the Ocean Total Surface Currents from Sentinel-1 Synthetic Aperture Radar<br>**Dr. Artem Moiseev (NERSC, Norway)** | 5.36 Jupyter notebook on Surface current estimation from Sentinel1 Doppler shift in the Med Sea<br>**Dr. Fabrice Collard (ODL)** | | https://esait.webex.com/weblink/register/r4c0f391116154f6203fb00ef7580e1b9 |
| 25th Feb 2025 | Wind and wave measurements from Space (Radar Scatterometry, Optical Glitter)) | 5.37 Radar Scatterometry over the ocean<br>**Ad Stoffelen, KNMI, the Netherlands** | 5.38 Vector winds derived from Radar Scatterometry over the ocean<br>**Ad Stoffelen, KNMI, the Netherlands** | | 5.39 Ocean Signatures from Optical Sun Glitter<br>**Dr Bertrand Chapron (IFREMER) and Dr Fabrice Collard (ODL)** | 5.40 Ocean surface roughness satellite Measurements in Synergy<br>**Dr Bertrand Chapron (IFREMER) and Dr Fabrice Collard (ODL)** | | https://esait.webex.com/weblink/register/r6327be37a6b82ba65892d068c9d619fc |

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| 4th Mar 2025 | Student Plans for activities abord the ship | 5.41 Presentation from each Student or Student group on research plans | | | 5.41 Presentation from each Student or Student group on research plans | | | | https://esait.webex.com/weblink/register/ra361b73210d3be6343160a884242a0d2 |
| 11th Mar 2025 | Air-sea interaction | 5.42 Physical mechanisms for air-sea gas exchange<br>**Prof. Anna Rutgersson** | | | 5.43 Calculating global atmosphere-ocean CO2 gas fluxes using satellite, in situ and modelling data (in synergy)<br>**Prof. Jamie Shutler, University of Exeter** | | | | https://esait.webex.com/weblink/register/r380a63e6bf190e2e418f45d56c8b08ac |
| 18th Mar 2025 | Ocean and Carbon | 5.44 Exploring the biological carbon cycle: where biology meets chemistry to connect atmosphere to seafloor<br>**Dr. Saskia Rühl PML** | | | 5.45 The amazing carbon cycle and the complete ocean carbon cycle: The ocean carbon sink, acidification and conservation<br>**Prof. Jamie Shutler, University of Exeter** | | | | https://esait.webex.com/weblink/register/rdced47fa542a06f22ea44778f5e59f36 |
| 25th Mar 2025 | Sea Ice measurements from space | 5.46 Tracking Sea ice from space<br>**Prof A. Shepherd (University of Northumbria)** | | | 5.47 Safe navigation in sea ice infested waters<br>**A. Korosev (NERSC, Norway)** | | | | https://esait.webex.com/weblink/register/r59ba1616e118cd61fccee892b3384272 |
| 1st Apr 2025 | Extremes and Climate Change | 5.48 ESA Satellite Oceanography: from exploration to operational oceanography and climate monitoring<br>**Dr Mark Drinkwater (ESA)** | | | 5.49 Observing Extreme Storm Events from Space<br>**Dr. Estel Cardellach (CISC)** | | | | https://esait.webex.com/weblink/register/r117ebd4b2896acd76467b1cb928281f8 |
| 8th Apr 2025 | Fiducial Reference Measurements<br>(**Extended session to 19:00**) | 5.50 Fiducial Reference Measurements (FRM): What are they and why are they important?<br>**Dr Emma Wooliams (NPL, London)** | 5.51 FRM and Sea Surface Temperature<br>**Dr Craig Donlon (ESA)** | | 5.52 FRM for sea surface salinity<br>**Dr Roberto Sabia (ESA)** | 5.53 FRM for System vicarious calibration and validation in ocean colour<br>**Dr Ewa Kwiatkowska (EUM)** | 5.54 FRM and Ocean Colour for System Vicarious Calibration of OCR<br>**Dr Hayley-Evers King and Dr Ewa Kwiatkowska (EUM)** | | https://esait.webex.com/weblink/register/r57f5802065a6a09f953180fa9043ef14 |

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| 15th Apr 2025 | **Preparing for the At-sea course**<br>***** 14:00 – 18:00 ***** | 14:00 (5.54) Life aboard the Statsraad Lehmkuhl<br>**Haakon Vatle, CEO Statsraad Lehmkuhl Foundation** | 14:30 (5.55) Practical information for Joining the ship<br>**Craig Donlon (ESA) and Haakon Vatle, CEO Statsraad Lehmkuhl Foundation** | | 15:00 (5.56) Tall Ships and Spaceships: an astronaut perspective of the ocean.<br>**Pablo Alvarez Fernandez (ESA)** | 16:00-18:30 (5.57) Extended Session: Personal Scientific Research Plans and Groupwork | | https://esait.webex.com/weblink/register/rb38d7dba6aea47ea0188809470bb00f8 |

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| 21st April - 6th June 2025 | **Ship departure/arrival dates:**<br><br>Embark Tromsø: 21 April 2025 18:00<br>Agent for shipping gear to the ship can be supplied by haakon.vatle@lehmkuhl.no. ***Please allow good time for clearances and be available to supervise the retrieval of your gear and transport to the ship.***<br>Depart Tromsø, Norway: 22 April 2025<br><br>Arrive Reykjavik, Iceland: 5-May 2025 10:00<br>Disembark Reykjavik: 6 May 2025 14:00<br>Embarkation Reykjavik: 6 May 2025 10:00Agent for shipping gear to the ship can be supplied by haakon.vatle@lehmkuhl.no. ***Please allow good time for clearances and be available to supervise the retrieval of your gear and transport to the ship.***<br>Depart Reykjavik Iceland: 7 May 2025<br><br>Arrive Mahon, Menorca on 1st June 2025 10:00.<br>Embarkation start at 11:00 AM (no later than 12:00 AM)<br>Depart for Nice 1 June 2025 at 14:00.<br><br>Arrive Nice: 3 June 2025 18:00<br>4-6th June 2025: One Ocean Science Conference https://one-ocean-science-2025.org/<br>4-5th June 2025: Earth Observation Action for a Sustainable Ocean (Round table discussions and demonstrations on the deck of the Statsraad Lehmkuhl by OTC25 teams and VIP.<br>**5th June 2025:** OTC25 team final dinner and social event aboard the ship<br>Agent for shipping gear back home from the ship can be supplied by haakon.vatle@lehmkuhl.no. **Please arrange all clearances early on 4th June.**<br>Disembark Nice 6 June 2025 10:00<br>Leg1: 14 days at sea, 1250 nm. Time allocated includes 4 hours per CTD assuming mean SOG of 4.8kt<br>Leg2: 29 days at sea, 2800 nm. Time allocated includes 4 hours per CTD assuming mean SOG of 5.0kt and short stop outside Mahon for VIP pickup | |

# 4. TOOLS TO BE USED DURING THE COURSE

## 4.1. ESA OCEAN VIRTUAL LABORATORY / ODL OVL PORTAL

OVL Portal aims to promote the synergistic use of Ocean Remote Sensing data in a wider context of Oceanic and Atmospheric models or in-situ data. It has a server side connected to data archives and two client sides, a web client (OVL Portal Web) and a standalone client (SEAScope SA).

You can access the OVL Portal Web portals using the following links:

ESA/SEOM Ocean Virtual Laboratory portal
http://ovl.oceandatalab.com

ESA Sentinel-1 quality control portal
http://mpc-sentinel1.oceandatalab.com

ESA/DUE Globcurrent portal
http://globcurrent.oceandatalab.com

EU FP7 SWARP (wave in ice) portal
http://swarp.oceandatalab.com

ESA SMOS Storm portal
http://smos-storm.oceandatalab.com

CNES Aviso'VIZ altimetry portal
http://aviso.oceandatalab.com

CNES PEPS test portal
http://peps.oceandatalab.com

ESA Sea Surface Salinity portal
http://pimep.oceandatalab.com

## 4.2. ESA SENTINEL APPLICATION PLATFORM (SNAP)

http://step.esa.int/main/toolboxes/snap/

SNAP is a common architecture for all Sentinel Toolboxes is being jointly developed by Brockmann Consult, Array Systems Computing and C-S called the Sentinel Application Platform(SNAP). The SNAP architecture is ideal for Earth Observation processing and analysis due the following technological innovations: Extensibility, Portability, Modular Rich Client Platform, Generic EO Data Abstraction, Tiled Memory Management, and a Graph Processing Framework.

SNAP includes the following features:

- Common architecture for all Toolboxes
- Very fast image display and navigation even of giga-pixel images
- Graph Processing Framework (GPF): for creating user-defined processing chains
- Advanced layer management allows adding and manipulation of new overlays such as images of other bands, images from WMS servers or ESRI shapefiles
- Rich region-of-interest definitions for statistics and various plots
- Easy bitmask definition and overlay
- Flexible band arithmetic using arbitrary mathematical expressions
- Accurate reprojection and ortho-rectification to common map projections,
- Geo-coding and rectification using ground control points
- Automatic SRTM DEM download and tile selection
- Product library for scanning and cataloguing large archives efficiently
- Multithreading and Multi-core processor support
- Integrated WorldWind visualisation

## 4.3. ESA Polar Thematic Exploitation Platform (TEP)

Polar TEP – Earth Observation Data Platform for the Polar Regions (polarview.org)

The Polar Thematic Exploitation Platform provides a complete working environment where users can access algorithms and data remotely, providing computing resources and tools that they might not otherwise have, avoiding the need to download and manage large volumes of data. This new approach removes the need to transfer large Earth Observation data sets around the world, while increasing the analytical power available to researchers and operational service providers.

Earth Observation is especially import in the polar regions at a time when climate change is having a profound impact and excitement about new economic opportunities is driving increased attention and traffic, resulting in concerns about the state of the region's delicate ecosystems. Developing tools to model, understand and monitor these changes is vitally important in order to better predict and mitigate the resulting global economic and environmental consequences. Polar TEP provides new ways to exploit EO data for research scientists, industry, operational service providers, regional authorities and in support of policy development.

## 4.4. JUPYTER NOTEBOOK

The IPython Notebook is now known as the Jupyter Notebook. It is an interactive computational environment, in which you can combine code execution, rich text, mathematics, plots and rich media. For more details on the Jupyter Notebook, please see the website at https://jupyter.org/

## 4.5. ESA FLUXENGINE ATMOSPHERE-OCEAN GAS FLUX CALCULATOR

http://www.oceanflux-ghg.org/Products/FluxEngine

The FluxEngine (http://www.oceanflux-ghg.org/Products/FluxEngine) is an open-source software toolbox for calculating atmosphere-ocean gas fluxes. The toolbox allows users to easily generate global and regional air-sea carbon dioxide flux data from model, in situ and Earth Observation data, and its air-sea gas flux calculation is user configurable. Whilst developed for carbon dioxide, much of the toolbox is applicable to other gases and the open-source nature of the toolbox enables it to be easily extended.

The FluxEngine can be used through a dedicated web interface at http://www.ifremer.fr/cersat1/exp/oceanflux/ or the open-source code can be downloaded from github https://github.com/oceanflux-ghg/FluxEngine

A tutorial explaining how to use the FluxEngine web-portal is available at http://www.ifremer.fr/cerweb/oceanflux/

Please cite the publication below when using the FluxEngine or any of its outputs:

> Shutler JD, Land PE, Piolle J-F, Woolf DK, Goddijn-Murphy L, Paul F, Girard-Ardhuin F, Chapron B, Donlon CJ (2016), FluxEngine: a flexible processing system for calculating atmosphere-ocean carbon dioxide gas fluxes and climatologies, Journal of Atmospheric and Oceanic Technology, doi: 10.1175/JTECH-D-14-00204.1.

# 5. LECTURES AND INTERACTIVE LECTURES

The following section provide an overview of each lecture provided during the training course. In some cases, there is an extensive reading list which is there for you should you need to follow up on the lecture.

All lectures will be recorded so that you will be able to revisit the lecture at your leisure to consolidate your knowledge.

In some cases, since everyone is an expert in a few things, you may find the lecture a little basic – this is because we want to ensure everyone has a chance to learn about things they are perhaps not familiar with. On board the ship, we expect that experts will help educate non-experts on board – including a cohort of citizen scientists who will sail with on aboard the Statsraad Lehmkuhl – you will be true ambassadors of ocean science.

## 5.1. INTRODUCTION TO THE TRAINING COURSE AND WHAT WE EXPECT FROM YOU

**Date and time:** November 12th, 16:30-17:15

**Lecturer:** Peter Thompson (UN Special Envoy for the Ocean), Dr Craig Donlon (ESA) and Dr Fabrice Collard (ODL)

**Aim of the lecture:** By the end of this lecture, you should understand the content and practical implementation of the Advanced Ocean Synergy Training Course, #OTC25

**Objectives of the lecture:**

OBJ-1: Review the #OTC25 overall aim and objectives

OBJ-2: Explain the course content and structure

OBJ-3: Review what is expected from you during #OTC25

**Abstract:**

Our goal during ESA #OTC25 is to help you to understand and exploit data from ESA and operational EO satellite missions for science and application development and prepare you as future ambassadors of Ocean Science. Peter Thompson, United Nations Special Envoy for the Ocean, Challenges students of the ESA #OTC25 as he explains:

*There can be no healthy planet without a healthy ocean and the ocean's health is currently measurably in decline. As the future generation of ocean scientists, it is upon your shoulders to advance ocean science to overcome the drastically incomplete knowledge we have of the ocean's properties. Only through respect for the best of ocean science can we achieve SDG 14 goal of conserving and sustainably using the ocean's resources.*

The ESA OTC25 is composed of three parts:

1. **A shore-based online component** that consists of 14 modules that are run once per week for a duration of 2 hours each. Each module will explain a different Earth Observation satellite measurement: how they work, how different instrument measure different parameters, and how we can apply derived data in different ways for ocean science applications. The shore-based course will focus on a virtual Voyage of the ship-based component of the training course.
2. **A ship-based component** aboard the tall ship Statsraad Lehmkuhl (https://lehmkuhl.no/en/) during the One Ocean expedition from Tromsø, Norway, to Nice, France, via Reykjavik, Iceland (see draft voyage track here). During this part the One Ocean Expedition we will depart Tromsø on 22nd April 2025 to sail 6200 nm in about 35 days arriving in Nice, France on 4th June 2025 as part of the opening events for the United Nations Ocean Conference 2025.
3. **Student reports.** A report from each group and from each Student (based on their personal studies) explaining the scientific work completed during the #OTC25 using the data collected aboard the ship and from satellite measurements is required. These deliveries are mandatory to be granted the ESA Training Course Certificate.

The OTC25 is an important and timely contribution to the United Nations Decade of Ocean Science for Sustainable Development and its slogan "*The science we need for the ocean we want*". As such, the training course, including both on-line lectures and an ocean science voyage aboard the Statsraad Lehmkuhl will serve as an unforgettable and powerful tool for outreach, inspiration and engagement for the ocean.

This lecture provides a broad-brush overview of the #OTC25 training course and discuss what is expected from you, as a student participating in the #OTC25 training course. It will include a discussion between you and the course coordinators.

### Software tools used in this lecture:

None

### Data sets used in this lecture:

None

### Key papers for background reading:


1. Skagseth et al, 2022, Arctic and Atlantic Waters in the Norwegian Basin, Between Year Variability and Potential Ecosystem Implications, *Front. Mar. Sci.,* 02 May 2022, Sec. Ocean Observation Volume 9 - 2022 | https://doi.org/10.3389/fmars.2022.831739
2. Spooner, P. T., Thornalley, D. J. R., Oppo, D. W., Fox, A. D., Radionovskaya, S., Rose, N. L., et al. (2020). Exceptional 20th century ocean circulation in the Northeast Atlantic. *Geophysical Research Letters*, 47, e2020GL087577. https://doi.org/10.1029/2020GL087577

3. Bonaduce et al, 2021, Ocean Mesoscale Variability: A Case Study on the Mediterranean Sea from a Re-Analysis Perspective, *Front. Earth Sci.,* 14 September 2021, Sec. Interdisciplinary Climate Studies, Volume 9 - 2021 | https://doi.org/10.3389/feart.2021.724879
4. Statsraad Lehmkuhl website. https://lehmkuhl.no/en/
5. One Ocean Expedition https://www.oneoceanexpedition.com/
6. Student handbook for the ship https://oceantrainingcourse2025.esa.int/wp-content/uploads/2024/06/English_Handbook_S_Lehmkuhl_LQ.pdf
7. United Nations Ocean Conference 2025 https://sdgs.un.org/conferences/ocean2025
8. UNOC25 Technical Conference: https://one-ocean-science-2025.org/home.html

## 5.2. STUDENT PROJECTS AND GROUP WORK – WORKING TOGETHER.

**Date and time:** Monday 12th September at 16:00

**Lecturer:** Prof. Johnny A. Johannesen (NERSC) and Dr Craig Donlon (ESA)

**Aim of the lecture:** At the end of this lecture the breakdown of the course into core thematic themes and the associated approach to student groups and group work will be explained.

**Objectives of the lecture:**

OBJ-1: Present the core thematic themes and the group breakdown

**Abstract:**

This lecture will discuss what is expected from you, as a student participating in the #OCT23 training course. It will include a live discussion between you and the course coordinators.

**Software tools used in this lecture:**

None

**Data sets used in this lecture:**

None

**Key papers for background reading:**

## 5.3. ROUND TABLE INTRODUCTION FROM STUDENTS AND LECTURER TEAM: WHO ARE YOU WHAT DO YOU WANT TO GET OUT OF THE COURSE?

**Date and time:** November 12th, 17:30-18:15

**Lecturer:** Dr Craig Donlon (ESA)

**Aim of the lecture:** At the end of this activity Students and the Lecture team will know who each other is and what is expected throughout the #OTC25.

**Objectives of the lecture:**

OBJ-1: Introduce Lecturers (2 slide presentation from each)

OBJ-2: Introduce Students (2 slide presentation from each)

OBJ-3: Review the expectations from Students and Lecturers

**Abstract:**

This lecture will be interactive. Each Lecturer and student will be asked to present 2 slides on who they are and what they want to achieve during the #OTC25 course.

**Software tools used in this lecture:**

None

**Data sets used in this lecture:**

None

**Key papers for background reading:**

1. Eid, J., Aanerud, M. & Enberg, K. Teaching sustainability at the high sea: the "One Ocean Expedition". Sustain Sci 19, 347–359 (2024). https://doi.org/10.1007/s11625-023-01419-9

## 5.4. OTC25 STUDENT INSTALLATION OF COMPUTER TOOLS AND TUTORIAL "CLINIC" TO TROUBLESHOOT ISSUES

**Date and time:** November 18th, 16:30-18:15

This drop-in session is dedicated to helping you get your computer up and running with OTC25 tools. If you have problems with installations this is the clinic to ask for advice and get those issues sorted.

## 5.5. THE ONEOCEAN EXPEDITION AND ESA OTC25

**Date and time:** November 19th, 16:30-16:50

**Lecturer:** Haakon Vatle (CEO Statsraad Lehmkuhl Foundation)

**Aim of the lecture:** At the end of this activity Students and the Lecture team will understand the OneOcean Expedition and #OTC25.

**Objectives of the lecture:**

OBJ-1: Introduce the tall ship Statsraad Lehmkuhl

OBJ-2: Explain the OneOcean Expedition

OBJ-3: Review life aboard the ship

OBJ-4: Explain how the ESA OTC25 contributes to the OneOcean Expedition

**Abstract:**

This lecture will introduce the tall ship Statsraad Lehmkuhl and provide a virtual tour of the ship highlighting life on board. The One Ocean Expedition will be presented and the context of the ESA OTC25 highlighted.

**Software tools used in this lecture:**

None

**Data sets used in this lecture:**

None

**Key papers for background reading:**

1. Statsraad Lehmkuhl website. https://lehmkuhl.no/en/
2. One Ocean Expedition https://www.oneoceanexpedition.com/
3. Student handbook for the ship https://oceantrainingcourse2025.esa.int/wp-content/uploads/2024/06/English_Handbook_S_Lehmkuhl_LQ.pdf
4. United Nations Ocean Conference 2025 https://sdgs.un.org/conferences/ocean2025
5. UNOC25 Technical Conference: https://one-ocean-science-2025.org/home.html

## 5.6. NORWEGIAN SEA FROM SPACE AND BELOW: SAILING THROUGH THE PUZZLING WAVES 125 YEARS AFTER HELLAND-HANSEN AND NANSEN

**Date and time:** November 19th, 16:50-17:10

**Lecturer:** Prof. Johnny Johannesen (NERSC)

**Aim of the lecture:** By the end of this lecture, you should understand the role of mesoscale variability for the northward transport of the Atlantic Water into the Norwegian Sea.

**Objectives of the lecture:**

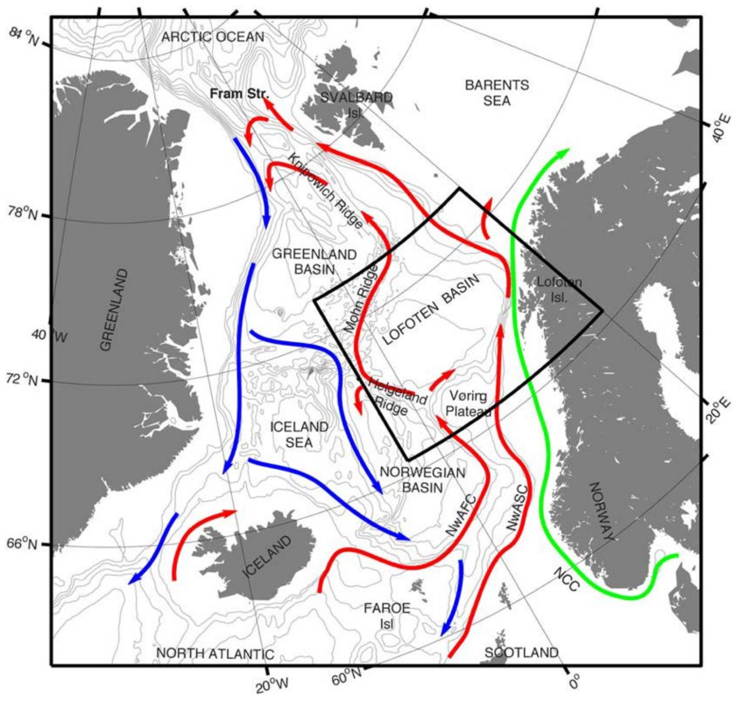
OBJ-1: Understand the various choices that can be made to conduct satellite validation

## Abstract:

The Norwegian Sea, including the Lofoten Basin, is recognized to be an eddy rich ocean. While Helland-Hansen and Nansen (1909) reported on findings of puzzling waves in the Norwegian Sea from analyses of water samples the 3D characteristics of eddies are now routinely investigated from a comprehensive multi-sensor database of satellite data collocated with Argo profiling floats, surface drifter data. And other in-situ data.

Figure 1: The surface circulation in the Nordic Seas (Helland-Hansen and Nansen, 1909).

As such, the poleward transport of warm Atlantic Water (AW) from the North Atlantic to the Nordic Seas, a key component in maintaining a relatively mild climate in the northwestern Europe (Rhines et al., 2008), can now be routinely monitored.




The circulation of the inflow region has been subject to investigations since Mohn (1887) and Helland-Hansen and Nansen (1909). Compared to the pre-satellite era, the launch of multi-satellite altimeter missions (in 1992) together with implementation of better interpolation schemes in satellite altimeter data processing and more accurate estimate of the geoid have facilitated the continuously improved monitoring of the ocean circulation (e.g., Mork and Skagseth, 2005; Berx et al., 2013; Chafik, 2012; Johannessen et al., 2014; Raj et al., 2015; Raj and Halo, 2016).

Figure 2. The Nordic Seas with schematic pathways indicating the overturning circulation from warm inflowing Atlantic Water in the surface (red) to cold and dense overflows to the deep North Atlantic (blue). The Norwegian Atlantic slope current (NwASC), here termed as the slope current, and the Norwegian Atlantic front current (NwAFC) are represented by red arrows. The fresh Norwegian Coastal Current (NCC) is indicated in green. See Furevik and Nilsen [2005] and Eldevik et al. [2009] for details. Gray isobaths are drawn for every 600 m.

The new reprocessing (Duacs/ AVISO, 2014) also includes important modifications of the processing chain (e.g., new sensor-specific instrumental and atmospheric corrections, revised inter-calibration, a new ocean tidal component, and a new reference field) adopted to convert raw altimeter sensor signals to along-track and gridded sea level data.

The warm AW enters the Nordic Seas through the passages between Iceland and the Faroe Islands and between the Faroe Islands and Scotland (Figure 1; Figure 2). The former is named the 'front current' while the latter is named the 'slope current'. The volume of AW transported poleward by the slope and front currents respectively are in the range of 2.7–4.4 Sv (Orvik and Skagseth, 2003; Sherwin et al., 2008; Berx et al., 2013) and 1.7–3.5 Sv (Orvik et al., 2001; Hansen et al., 2010; Mork and Skagseth, 2010). Analysis of the monthly surface velocities from 1993 to 2016 demonstrates significant influence of the large-scale atmospheric forcing associated with the North Atlantic Oscillation (NAO). Moreover, a significant increase in surface velocities along the slope current, front current and the Norwegian Coastal Current are found during winter. The AW heat transport also influences the sea ice cover and local climate in the Barents Sea (Sandø et al., 2010; Årthun et al., 2012) and along the west coast of Svalbard (Walczowski and Piechura, 2011). Several studies have, moreover, shown the gradual transformation of AW along its pathways in the Nordic Seas to play a major role in the formation of overflow waters (e.g., Isachsen et al., 2007; Eldevik et al., 2009), which in turn is a main source for the North Atlantic Deep Water (Dickson and Brown, 1994).

Along the northward pathway of the AW mesoscale eddies ranging from the baroclinic Rossby radius of deformation to 100 km are triggered by instabilities of the front current and slope current. These eddies absorb both energy and heat from the mean flow, and as such influence the total northward heat and salt transport of AW by advective trapping [Dong et al., 2014], stirring and mixing [Morrow and Le Traon, 2012]. Their influence on the biology of the upper ocean in this highly rich marine ecosystem is also n qualitatively well know (Samuelsen et al., 2012; Godø et al., 2012).

In this lecture the role of the mesoscale variability for the northward transport of the Atlantic Water into the Norwegian Sea will be addressed. Specific examples will be provided using visualization tools (e.g. NARVAL and OVL Portal). It will also highlight how the sail voyage through this ocean region will be planned and implemented weather permitting.

### Software tools used in this lecture:

1. visualization tools (e.g. NARVAL and OVL Portal).

### Data sets used in this lecture:

1. Data within visualization tools (e.g. NARVAL and OVL Portal).

### Key papers for background reading:

1. Helland-Hansen and Nansen (1909)
2. Rhines et al., 2008)
3. Sandø et al., 2010;
4. Årthun et al., 2012

5. Walczowski and Piechura, 2011
6. Isachsen et al., 2007;
7. Eldevik et al., 2009
8. Dickson and Brown, 1994
9. Orvik and Skagseth, 2003;
10. Sherwin et al., 2008;
11. Berx et al., 2013
12. Orvik et al., 2001;
13. Hansen et al., 2010;
14. Mohn (1887)
15. Mork and Skagseth, 2010
16. Mork and Skagseth, 2005;
17. Berx et al., 2013;
18. Chafik, 2012;
19. Johannessen et al., 2014;
20. Raj et al., 2015;
21. Raj and Halo, 2016).
22. Dong et al., 2014
23. Morrow and Le Traon, 2012
24. Samuelsen et al., 2012;
25. Godø et al., 2012

## 5.7. THE NORTHEAST ATLANTIC OCEAN: FROM SPACE AND BELOW.

**Date and time:** November 19th, 17:30-17:50

**Lecturer:** Craig Donlon (ESA/ESTEC)

**Aim of the lecture:** By the end of this lecture, you should be familiar with the main ocean and meteorological characteristics of the North East Atlantic Ocean using satellite data.

**Objectives of the lecture:**

OBJ-1: Review the main oceanographic and meteorological characteristics of the NE Atlantic Ocean

**Abstract:**

The northeastern Atlantic Ocean spans from the western coast of Europe to the eastern coast of North America, extending northwards towards the Arctic Ocean. It is a dynamic and complex region characterized by diverse oceanographic and meteorological features (Spooner et al, 2020). The seasonal meteorology is characterized by varying weather patterns, temperatures, and atmospheric conditions throughout the year. Seasonal changes in this region have significant impacts on the weather, climate, and marine conditions in the surrounding regions, including Western Europe and the eastern coast of North America. During winter (Dec-Feb) frequent low-pressure systems and associated storms move eastward from the North American continent across the Atlantic bringing

strong winds, heavy rainfall, and occasionally snow to the northern and higher-altitude regions. This period experiences the highest frequency of Atlantic storms, including extratropical cyclones. Spring (Mar-May) sees a gradual warming trend transitional season with variable weather. Low-pressure systems continue to affect the region, but there are also periods of high pressure bringing calmer and clearer conditions. Sea surface temperatures begin to rise. Phytoplankton blooms begin in spring as increasing sunlight and rising water temperatures stimulate primary productivity. During summer (Jun-Aug) high-pressure systems often dominate leading to more stable, dry, and sunny conditions. However, the region can still experience occasional low-pressure systems and Atlantic storms. Summer is a period of high biological activity, with continued phytoplankton blooms and active marine life.

The northeastern Atlantic Ocean is a critical component of the global oceanic system, influencing climate, weather, and marine ecosystems across the northern hemisphere. **1. General Geography and Boundaries**

- **Location:** The northeastern Atlantic Ocean spans from the western coast of Europe to the eastern coast of North America, extending northwards towards the Arctic Ocean.
- **Major Subdivisions:** This region includes the North Sea, the Irish Sea, the Norwegian Sea, and parts of the Atlantic Ocean proper.

**2. Water Masses and Circulation**

- **North Atlantic Drift:** This is an extension of the Gulf Stream that carries warm, salty water from the tropics towards Europe, influencing the climate of Western Europe.
- **Gulf Stream:** Originating in the Gulf of Mexico, the Gulf Stream moves northward along the eastern coast of the United States before veering eastward into the Atlantic.
- **Subpolar Gyre:** In the northern part of the northeastern Atlantic, this gyre is characterized by cold, nutrient-rich waters that support high biological productivity.
- **Iceland-Scotland Ridge:** This underwater ridge acts as a barrier for water masses and influences the mixing of warm and cold waters between the Atlantic and the Arctic Oceans.

**3. Temperature and Salinity**

- **Temperature:** Water temperatures vary significantly. The western part, influenced by the Gulf Stream, is relatively warm. In contrast, the northeastern part, influenced by the Arctic waters, is colder.
- **Salinity:** The salinity is higher in the southern and western areas due to the influence of the Gulf Stream and lower in the northern areas where freshwater from ice melt and precipitation dilutes the seawater.

**4. Marine Ecosystems**

- **Phytoplankton Blooms:** The northeastern Atlantic is known for its seasonal phytoplankton blooms, which are influenced by nutrient availability and water temperature.

- **Marine Life:** This region supports a rich variety of marine life, including commercially important fish species like cod, herring, and mackerel. It's also home to marine mammals such as whales and seals.

5. Climate Influence

- **Climate:** The northeastern Atlantic plays a significant role in the climate of nearby landmasses. The warm waters of the North Atlantic Drift help moderate the climate of Western Europe, making it milder compared to other regions at similar latitudes. **Weather Patterns:** This region is prone to frequent weather changes, including storm systems originating from the Atlantic, which can impact both Europe and North America.

The Mediterranean Outflow is a crucial component of the Atlantic Ocean's circulation system and plays a significant role in the exchange of water between the Mediterranean Sea and the Atlantic Ocean. Its influence extends beyond oceanography, affecting climate and marine ecosystems in the surrounding regions. The Mediterranean Outflow refers to the movement of water from the Mediterranean Sea into the Atlantic Ocean. The outflow water exits the Mediterranean Sea through the Strait of Gibraltar, which is a narrow and shallow passage connecting the Mediterranean with the Atlantic Ocean. Mediterranean water is characterized by its high salinity and relatively warm temperatures due to high evaporation rates and limited inflow of fresh water. Due to its higher salinity and temperature, Mediterranean water is denser than the surrounding Atlantic water. As a result, the outflowing water tends to sink to. A depth of ~1000, spreading westward and mixing across the Atlantic Ocean. plays a key role in the formation of Mediterranean Intermediate Water, which is an important component of the Atlantic Meridional Overturning Circulation (AMOC). This water mass affects the vertical stratification and overall circulation of the Atlantic Ocean impacting nutrient distribution, temperature, and salinity patterns in the North Atlantic. The outflow is significant because it involves the exchange of water between these two major bodies of water, and it has important implications for oceanography and climate.

## Software tools used in this lecture:

1. Ocean Virtual Laboratory OVL Portal

## Data sets used in this lecture:

2. Ocean Virtual Laboratory OVL Portal data sets

## Key papers for background reading:

1. Johnson et al, Biogeographical regions in Europe: The North-east Atlantic Ocean- huge, deep and heavily exploited, EEI report, Norwegian Institute for Water Research (NIVA), https://www.eea.europa.eu/publications/report_2002_0524_154909/regional-seas-around-europe/nea_ocean.pdf

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14. Hakkinen, S., & Rhines, P. B. (2009). Shifting surface currents in the northern North Atlantic Ocean. Journal of Geophysical Research, 114, C04005. https://doi.org/10.1029/2008JC004883
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## 5.8. THE MEDITERRANEAN SEA: FROM SPACE AND BELOW.

**Date and time:** November 19th, 17:50-18:15

**Lecturer:** Fabrice Collard (Ocean Data Lab)

**Aim of the lecture:** By the end of this lecture, you should understand the main oceanographic and meteorological characteristics of the western Mediterranean Sea.

**Objectives of the lecture:**

OBJ-1: Review the main oceanographic and meteorological characteristics of the Western Med Sea

OBJ-2: Use OVL web portal to explore the characteristics of the Western Med Sea.

**Abstract:**

The Western Mediterranean Sea, located between the Iberian Peninsula, the Balearic Islands, Sardinia, Corsica, and the North African coast, is characterized by distinct oceanographic and meteorological features influenced by geography, atmospheric circulation, and seasonal variations.

1. Oceanographic Characteristics

- **Water Circulation:** The Western Mediterranean has a counterclockwise circulation, driven by a combination of inflows from the Atlantic Ocean and regional winds. The main currents are:
  - **Atlantic Water Inflow:** Surface water from the Atlantic Ocean enters the Mediterranean through the Strait of Gibraltar. This water is warmer, less saline, and more nutrient-rich compared to Mediterranean waters.
  - **Liguro-Provençal-Catalan Current:** A prominent westward surface current flows along the northern coast, driven by wind and temperature gradients, moving from the Ligurian Sea past the Gulf of Lions and towards the Balearic Islands.
  - **Algerian Current:** On the southern side, a strong current flows eastward along the Algerian coast, creating meanders and eddies.
- **Water Masses:**
  - **Surface Waters:** Characterized by Atlantic-origin water, these have lower salinity and temperature compared to deeper layers.
  - **Intermediate Waters:** The Levantine Intermediate Water (LIW) forms in the Eastern Mediterranean, flowing westward into the Western Mediterranean and settling at intermediate depths (~200-600 meters), with higher salinity and temperature than the surface layers.
  - **Deep Waters:** Western Mediterranean Deep Water (WMDW) forms during winter in the Gulf of Lions due to cooling and sinking, contributing to the thermohaline circulation.
- **Salinity and Temperature:**
  - Salinity generally increases moving eastward due to higher evaporation rates. In the Western Mediterranean, surface salinity ranges from 36 to 38 PSU (practical salinity units).
  - Surface temperatures vary seasonally, from about 14–16°C in winter to 23–27°C in summer. Deeper layers maintain more stable temperatures (~12–13°C in intermediate and deep waters).
- **Tides and Waves:** The Mediterranean experiences micro-tidal conditions, with tidal ranges typically below 1 meter. However, waves, particularly in winter, can be

influenced by strong winds and storms, especially in the Gulf of Lions and the Balearic Sea.

2. Meteorological Characteristics

- **Winds:** Several dominant wind systems affect the Western Mediterranean:
    - **Mistral:** A strong, cold north-westerly wind that accelerates as it funnels through the Rhône Valley and into the Gulf of Lions. It is particularly intense in winter and spring, contributing to the formation of deep water masses.
    - **Tramontane:** A northerly or north-westerly wind, similar to the Mistral, affecting the region between France and Spain.
    - **Sirocco:** A hot, dry wind originating from the Sahara Desert, blowing from the southeast, often bringing dust and sometimes causing temperature increases and visibility reduction.
    - **Levanter:** An easterly wind blowing through the Strait of Gibraltar, impacting the westernmost Mediterranean.
- **Storms and Precipitation:** The Western Mediterranean is susceptible to seasonal storms, particularly in autumn and winter, with cyclogenesis often occurring over the region. These storms can bring heavy rains, particularly along coastal areas of Spain, France, and Italy.
- **Temperature:** The Western Mediterranean has a typical Mediterranean climate, characterized by hot, dry summers and mild, wet winters. Average sea surface temperatures (SST) are highest in late summer, around 25–27°C, and lowest in winter, around 12–16°C.
- **Evaporation and Precipitation:** The region is a net evaporative basin, with evaporation rates exceeding precipitation and river inflows. This creates a deficit, balanced by inflow from the Atlantic. Evaporation peaks in summer, contributing to the high salinity of the water.

Summary:

The Western Mediterranean Sea is a dynamic system influenced by complex water circulation patterns, strong winds (especially Mistral and Tramontane), seasonal temperature and salinity variations, and limited tides. Its deep-water formation processes and regional weather patterns, including cyclogenesis and strong winds, are critical for both its oceanographic structure and broader climatic influence. We'll walk you through all these patterns using satellite observations to illustrate them.

Software tools used in this lecture:

1. Ocean Virtual Laboratory OVL Portal

Data sets used in this lecture:

2. Ocean Virtual Laboratory OVL Portal data sets

Key papers for background reading:

1. Oceanography of the Mediterranean Sea. An Introductory Guide. 2022. Katrin Schroeder & Jacopo Chiggiato https://doi.org/10.1016/C2020-0-00371-3
2. López-Jurado, J. & Balbín, Rosa & Amengual, B. & Aparicio-González, Alberto & Fernández de Puelles, Mª & Garcia-Martinez, Mcarmen & Gazá, M. & Jansa, Jiri & Morillas, Ana & Moya, Francina & Santiago, Rocio & Serra, M. & Vargas-Yáñez, Manuel & Vicente, L.. (2015). The RADMED monitoring program: towards an ecosystem approach. Ocean Science Discussions. 12. 645-671. 10.5194/osd-12-645-2015.

## 5.9. INTRODUCTION TO OVL PORTAL AND SEA SCOPE TOOLS

**Date and time:** 26th November 2024 16:30-18:15

**Lecturer:** Dr Lucile Gaultier, Dr Fabrice Collard (ODL) and Dr Ziad El Khoury Hanna (ODL)

**Aim of the lecture:** At the end of this interactive lecture, you should be able to use the OVL web Portal to investigate the OTC25 regions from space.

**Objectives of the lecture:**

OBJ-1: To demonstrate and review the OVL Portal application through interactive activities focussed on the OTC25 voyage region.

**Abstract:**

The Ocean Virtual Laboratory (OVL) is a virtual platform to allow oceanographers to discover the existence and then to handle jointly, in a convenient, flexible and intuitive way, the various co-located EO datasets and related model/in-situ datasets over dedicated regions of interest with a different multifeed point of view. The Ocean Virtual Laboratory portal is based on OVL Portal, an open source web viewer for satellite, model and in-situ data, by OceanDataLab.

The Ocean Virtual Laboratory (OVL) is a virtual platform to allow oceanographers to discover the existence and then to handle jointly, in a convenient, flexible and intuitive way, the various co-located EO datasets and related model/in-situ datasets over dedicated regions of interest with a different multifeed point of view.

Make sure to explore OceanDataLab and OVL YouTube channels, where you can find videos demonstrating this portal in action. These videos showcase finding interesting cases of synergy between various sensors and data sources. You can find examples in the tutorials playlist as well as in other videos released during international events over the past years.

The Ocean Virtual Laboratory (https//ovl.oceandatalab.com) is funded by the European Space Agency. The main objective of the project is to develop a virtual platform to allow

oceanographers to discover the existence and then to handle jointly, in a convenient, flexible and intuitive way, the various co-located EO datasets and related model/in-situ datasets over dedicated regions of interest with a different multifaceted point of view.

**Software tools used in this lecture:**

1. Ocean Virtual Laboratory OVL Portal (https//ovl.oceandatalab.com)

**Data sets used in this lecture:**

1. Ocean Virtual Laboratory OVL Portal

**Key papers for background reading:**

1. OVL Portal Online tutorials: https://www.youtube.com/@oceandatalab
2. OVL Portal How To: https://www.youtube.com/playlist?list=PL_Nrq3gZvmM-rrE64qr7QqzQir23kzol1
3. EGU 2020 playlist
4. ESA Φ-WEEK 2021 playlist

## 5.10. INTRODUCTION TO SEASCOPE VISUALISATION AND ANALYSES TOOLS

**Date and time:** 26th November 2024 16:30-18:15

**Lecturer:** Dr Lucile Gaultier (ODL), Dr Fabrice Collard (ODL)

**Aim of the lecture:** Learn to use SEAScope for visualisation of data and analyses

**Objectives of the lecture:**

OBJ-1: **Install SEAScope, add data**

OBJ-2: Install the SEAScope application on your computer

OBJ-3: To demonstrate and review the SEAscope application through interactive activities focussed on the OTC25 voyage.

**Abstract:** SEAScope (https://seascope.oceandatalab.com/) is the next generation open source synergy analysis standalone tool. SEAScope is a 3D visualisation and analysis application for satellite, in-situ and numerical model data. Modelizing the Earth as a sphere allows SEAScope to ignore projection issues and lets you display data everywhere on the planet.

The viewer offers advanced rendering functionalities that ease the detection of synergies between several sources of observations and simulations. It also features tools to help users design and test algorithms on a large variety of data with immediate visual feedback.

Today available for Linux, Windows and macOS and working with local datasets, it allows an even richer and fluid visualization experience, and more interaction and manipulation with the datasets thanks to an extensive use of the GPU and the two way communication with iPython notebooks.

More information on SEAScope is available on https://seascope.oceandatalab.com

During the practical, we will learn to open SEAScope, add data and interact with the stand alone application using data of interest for the OTC25 voyage.

**Software tools used in this lecture:**

1. Ocean Virtual Laboratory OVL Portal (https//ovl.oceandatalab.com)
2. SEAScope application (https://seascope.oceandatalab.com/)

**Data sets used in this lecture:**

1. IDF netCDF data formatted for SEAScope

**Key papers for background reading:**

1. SEAScope How To videos: https://www.youtube.com/playlist?list=PL_Nrq3gZvmM_C8baJBiNEzMjg0Hg7FIgK
2. SEAScope website: https://seascope.oceandatalab.com
3. SEAScope tutorials: https://seascope.oceandatalab.com/tutorials.html
4. SEAScope manual: https://seascope.oceandatalab.com/docs/seascope_user_manual_20241001.pdf
5. EGU 2020 playlist
6. ESA Φ-WEEK 2021 playlist
7. SEAscope tutorials: https://seascope.oceandatalab.com/tutorials.html

## 5.11. THERMAL IMAGE INTERPRETATION AND ESTIMATION OF SEA SURFACE TEMPERATURE

**Date and time:** 3rd December 2024, 16:30-17:10

**Lecturers:** Dr Gary Corlett (EUMETSAT) and Dr Ben Loveday (EUMETSAT/Innoflair)

**Aim of the session:** By the end of this interactive session, which includes both a lecture and practical component, you should be able to understand how sea surface temperature (SST) is measured from space, recognise the advantages and disadvantages of using SST imagery for ocean studies, and understand how to work with single sensor SST products to determine data quality.

**Pre-session expectation:** Owing to the limited time available it is <u>essential</u> that you read Minnett et al. (2019) before the lecture as many concepts will only briefly be covered.

## Objectives:

OBJ-1: Understand instruments used to measure SST from space focussing on SLSTR.

OBJ-2: Assess SLSTR products for quality and identifying clouds.

## Abstract:

Sea surface temperature (SST) is an important geophysical parameter, being the boundary condition used in the determination of fluxes at the atmosphere/ocean interface. Globally, this is vital for studies of the Earth's heat balance and changes in atmospheric or oceanic circulation patterns (such as El Niño). On a more local scale, SST can be used operationally as the foundation for numerical weather forecasts, to assess eddies, fronts and upwellings for marine navigation, and to track biological activity (e.g. fish migration). Historically, SST has been measured mainly by ships and buoys, but are limited in both coverage and accuracy. Satellites have improved our ability to measure SST by allowing more frequent and consistent global coverage.

The basis for SST measurement from space is that all surfaces emit spectral radiation depending on their temperature and defined by Planck's radiation law. For the Earth's oceans, the peak in the Planck function occurs in the infrared (IR) region between 9 µm and 11 µm. The signal from the surface is, of course, attenuated by the atmosphere, so SST is usually derived at wavelengths around 3.7 µm and/or near 10 µm, where such atmospheric effects are minimal; note the 3.7 µm channel is more sensitive to SST (think why this might be) but is used only for night time measurements because of solar contamination during the day. As these bands are sensitive to the atmosphere (including the effects of clouds and aerosols), SST retrieval from IR radiometers requires correction of the measured signal and consequently can only be made for cloud-free pixels. Platforms for measuring SST operate in both low-Earth (LEO) and geostationary Earth orbits (GEO).

In this session, we will first look at the basics of measuring SST from space, including consideration of the sensor type and orbit, how radiation from the Earth is modified before it reaches the sensor and the depth of the SST measurement (think why is the depth important). We will follow this with a practical session where we work directly with the IR SST products from the SLSTR sensor. During the practical, we will consider some example imagery of the region, assessing its quality, and learning how to develop and apply cloud masks.

**Software tools used in this lecture:**

1. Python-based Jupyter Notebooks. If you have not worked in Python or with Jupyter Notebook before, you may wish to briefly consult the following;
   a. Free Python tutorial for beginners
   b. Jupyter Lab documentation and user guide

Our practical demonstrations will use Python-based Jupyter Notebooks. These will be made available on a remote cloud service (e.g. Binder) for the purposes of our demonstration, but will also be available for cloning to local systems for use on the ship, should bandwidth permit.

**Data sets used in this lecture:**

1. Copernicus Sentinel-3 SLSTR Level 2 WST sea surface temperatures

**Key papers for background reading:**

1. Minnett, P. J., Alvera-Azcárate, A., Chin, T. M., Corlett, G. K., Gentemann, C. L., Karagali, I., et al. (2019). Half a century of satellite remote sensing of sea-surface temperature. Remote Sensing of Environment, 233, 111366. https://doi.org/10.1016/j.rse.2019.111366
2. SLSTR level-1 data guide
3. Sentinel-3 sea surface temperature (SST) level 2 data guide

## 5.12. SELECTING, EXPLORING AND VALIDATING SEA SURFACE TEMPERATURE PRODUCTS

**Date and time:** 3rd December 2024, 17:30 -18:15

**Lecturers:** Dr Gary Corlett (EUMETSAT) and Dr Ben Loveday (EUMETSAT/Innoflair)

**Aim of the session:** By the end of this interactive session, which includes both a lecture and practical component, you should be able to understand how multi-sensor sea surface temperature (SST) products are created, how to select the best ones for your purpose and how to work with and validate them.

**Pre-session expectation:** Owing to the limited time available it is essential that you read Donlon et al. (2007) before the lecture as many concepts will only briefly be covered.

**Objectives:**

OBJ-1: Recall some of the single- and multi-sensor SST products that are available.

OBJ-2: Understand how to select the best SST product for your application and validate it.

OBJ-3: Explore how SST products can be used to investigate oceanographic processes and various temporal and spatial scales.


## Abstract:

Analysing sea surface temperature (SST) gives us extensive information on ocean dynamics at temporal and spatial scales, which vary from diurnal to multi-decadal, sub-mesoscale to global. However, while selecting the correct SST product is essential to conducting these analyses, the number available, and subtle differences in their nature, makes the landscape complicated for users.

In this session we will discuss some differences in sea surface products at various processing levels, outlining how key organisations, such as the Group for High Resolution Sea-Surface Temperature (GHRSST), coordinate activities and how data producers, including EUMETSAT and the Copernicus Marine Service, facilitate the production of single- and multi-sensor SST products. We will discuss data set selection, using examples of regional oceanographic phenomena that are relevant to the cruise.

The session will conclude with a practical demonstration on how to work with multi-sensor SST products, and how to validate them against *in situ* temperature measurements.


## Software tools used in this lecture:

2. Python-based Jupyter Notebooks. If you have not worked in Python or with Jupyter Notebook before, you may wish to briefly consult the following;
    a. Free Python tutorial for beginners
    b. Jupyter Lab documentation and user guide

Our practical demonstrations will use Python-based Jupyter Notebooks. These will be made available on a remote cloud service (e.g. Binder) for the purposes of our demonstration, but will also be available for cloning to local systems for use on the ship, should bandwidth permit.

## Data sets used in this lecture:

1. Copernicus Marine Service (CMEMS) Level-4 SST products; in situ SST data from various platforms

## Key papers for background reading:


1. Donlon, C. J., Robinson, I., Casey, K. S., Vazquez-Cuervo, J., Armstrong, E., Arino, O., et al. (2007). The global ocean data assimilation experiment high-resolution sea surface temperature pilot project. Bulletin of the American Meteorological Society, 88(8), 1197–1213. https://doi.org/10.1175/BAMS-88-8-1197
2. Copernicus Marine Service Level-4 CCI/C3S reprocessed SST record documentation

## 5.13. MICROWAVE RADIOMETRY OF THE OCEANS FROM SPACE

**Date and time:** December 10th 2024 16:30-17:50

**Lecturer:** Dr. Craig Donlon (ESA)

**Aim of the lecture***:* This lecture will present theoretical principles of microwave radiometry from space.

### Objectives of the lecture

OBJ-1: Overview of general principles of microwave radiometry and the ocean

OBJ-2: Review specific challenges for satellite sensors when using microwave radiometers focussing on the Copernicus Imaging Microwave Radiometer.

### Abstract:

Measuring ocean surface signals from space in the microwave region of the electromagnetic spectrum presents significant advantages including near all-weather quasi global coverage with daily repeat.  Microwave emissions from the sea surface are complex and are driven by a variety of processes (temperature, salinity, surface roughness, precipitation…) allowing multi-frequency sensors to retrieve a wide variety of geophysical products at the same time and location.  However, challenges related to the wavelength of interest limit observations to coarse resolution. New satellite payloads, such as the Copernicus Imaging Microwave Radiometer (CIMR, see https://www.esa.int/Applications/Observing_the_Earth/Copernicus/CIMR ) are designed to mitigate these challenges.

This lecture will review the basic principles of Microwave radiometry from space using the JAXA Advanced Microwave Scanning Radiometer (AMSR/2) and CIMR mission.

### Software tools used in this lecture:

None

### Data sets used in this lecture:

None

### Key papers for background reading:

1. Pearson, Kevin, Christopher Merchant, Owen Embury, and Craig Donlon. 2018. "The Role of Advanced Microwave Scanning Radiometer 2 Channels within an Optimal Estimation Scheme for Sea Surface Temperature" Remote Sensing 10, no. 1: 90. https://doi.org/10.3390/rs10010090
2. Kilic, L., Prigent, C., Aires, F., Boutin, J., Heygster, G., Tonboe, R. T. et al. (2018). Expected performances of the Copernicus Imaging Microwave Radiometer (CIMR) for an all-weather and high spatial resolution estimation of ocean and sea ice parameters. *Journal of Geophysical Research: Oceans*, 123, 7564–7580. https://doi.org/10.1029/2018JC014408
3. Donlon, C. J., 2024, Copernicus Imaging Microwave Radiometer (CIMR) Mission Requirements Document, version 5.0, ESA-EOPSM-CIMR-MRD-3236,

https://esamultimedia.esa.int/docs/EarthObservation/CIMR-MRD-v5.0-20230211_(Issued).pdf

## 5.14. SALINITY AND EXTREME WIND SPEEDS USING MICROWAVE IMAGING

**Date and time: December 10th 2024 16:50-17:10**

**Lecturer:** Nicolas Reul (IFREMER)

**Aim of the lecture***:* This lecture will present theoretical principles and experimental data on the microwave radiometry of (i) sea surface Salinity and (ii) near-surface wind speed in extreme conditions.

**Objectives of the lecture**

OBJ-1: learn specificities of the sea surface salinity remote sensing with L-band radiometers

OBJ-2: review of all weather wind speed retrievals from radiometer operated at C- and X-band as well as L-band frequencies.

**Abstract:**

Operated since the end of 2009, the European Space Agency (ESA) Soil Moisture and Ocean Salinity (SMOS) satellite mission is the first orbiting radiometer that collects regular and global observations from space of two Essential Climate Variables of the Global Climate Observing System: Sea Surface Salinity (SSS) and Soil Moisture. The National Aeronautics and Space Administration (NASA) Aquarius mission, with the primary objective to provide global SSS measurements from space operated from mid-2011 to mid-2015. NASA's Soil Moisture Active-Passive (SMAP) mission, primarily dedicated to soil moisture measurements, but also monitoring SSS, has been operating since early 2015. The primary sensors onboard these three missions are passive microwave radiometers operating at 1.4 GHz (L-band). SSS is retrieved from radiometer measurements of the sea surface brightness temperature (TB). In this lecture, we first provide a historical review of SSS remote sensing with passive L-band radiometry beginning with the discussions of measurement principles, technology, sensing characteristics and complementarities of the three aforementioned missions. The assessment of satellite SSS products is then presented in terms of individual mission characteristics, common algorithms, and measurement uncertainties, including the validation versus in situ data, and, the consideration of sampling differences between satellite SSS and in situ salinity measurements. We next review the major scientific achievements of the combined first 10 years of satellite SSS data, including the insights enabled by these measurements regarding the linkages of SSS with the global water cycle, climate variability, and ocean biochemistry. We also highlight the new ability

provided by satellites to monitor mesoscale and synoptic-scale SSS features and to advance our understanding of SSS' role in air-sea interactions, constraining ocean models, and improving seasonal predictions. An overview of satellite SSS observation highlights during this first decade and upcoming challenges are then presented.

Originally, microwave radiometers were developed for measuring atmospheric parameters (water vapor, liquid water, temperature, ozone content, ...) in the atmosphere of the Earth or of other planets. However, it was realized since the mid 1960’s that in frequency bands not attenuated by the atmosphere, their measurements are also sensitive to the roughness of the ocean surface. It was also realized that a combination of different electromagnetic frequencies (typically from 5 to 90 GHz) was useful to separate atmospheric effects from surface effects. The first wind speed maps provided at the global scale were obtained from observations at 10.7 GHz of the Scanning Multi-Channel Microwave Radiometer on the Seasat satellite launched in 1978 (Njoku and Swanson, 1983). Since then, this approach has been extended (other frequencies or combination of frequencies, usually in C and X-bands) and operationally used from various series of satellites. A well-known example is the series of the Defense Meteorological Satellite Program (DMSP) which carries the scanning radiometer SSM/I (Special Sensor Microwave/Imager, see Hollinger, 1989) or its successor (Special Sensor Microwave Imager / Sounder (SSMIS). In spite of some limitations, particularly in regions affected by rain, such observations of wind speed from radiometer measurements are now systematically used in the operational meteorological centres forecasting systems. Since the 2000, new types of microwave radiometers at lower frequencies (L-Band) allow also to estimate the surface wind speed with a good accuracy, and indeed with a much better performance in rain or high wind conditions than that for higher frequency radiometers (Reul et al., 2012; Meissner et al., 2021). In this lecture, we shall present surface wind speed radiometer measurement principle and equations in high wind speed conditions. This will include all weather wind speed retrievals from radiometer operated at C- and X-band as well as L-band frequencies.

### Software tools used in this lecture:

1. Matlab, OVL Portal

### Data sets used in this lecture:

1. SSMI, AMSR-E, AMSR2, WindSat, SMOS and SMAP

### Link to data sources for further downloads:

1. Remote sensing system geophysical products: https://www.remss.com/ (SSMI,AMSR-E, AMSR2, WindSat, and SMAP)
2. SMOS high surface wind data https://www.smosstorm.org/

### Key papers for background reading:

1. Reul N et al. (2020). Sea surface salinity estimates from spaceborne L-band radiometers: An overview of the first decade of observation (2010–2019). Remote Sensing Of Environment, 242, 111769 (37p.), https://doi.org/10.1016/j.rse.2020.111769 .
2. Meissner, T., Ricciardulli, L., Manaster, A., (2021), "Tropical cyclone wind speeds from WindSat, AMSR and SMAP: Algorithm development and testing", Remote Sens. 13, 1641. https://doi.org/10.3390/rs13091641
3. Reul, N., Tenerelli, J., Chapron, B., Vandemark, D., Quilfen, Y., and Kerr, Y., 2012, "SMOS satellite L-band radiometer: A new capability for ocean surface remote sensing in hurricanes", J. Geophys. Res., 117, C02006, doi:10.1029/2011JC007474
4. Knaff J.A. et al. (2021). Estimating tropical cyclone surface winds: Current status, emerging technologies, historical evolution, and a look to the future . Tropical Cyclone Research And Review , 10(3), 125-150 . Publisher's official version : https://doi.org/10.1016/j.tcrr.2021.09.002 , Open Access version : https://archimer.ifremer.fr/doc/00723/83460/
5. Bourassa M. et al. (2019). Remotely Sensed Winds and Wind Stresses for Marine Forecasting and Ocean Modeling . Frontiers In Marine Science , 6(443), 28p. Publisher's official version : https://doi.org/10.3389/fmars.2019.00443 ,


## 5.15. OCEAN COLOUR RADIOMETRY (OCR) OF THE OCEAN FROM SPACE

**Date and time:** 17th December 2024, 16:30-16:50

**Lecturer:** Dr. Astrid Bracher (AWI) and Dr Hayley Evers-King (EUMETSAT)

**Aim of the lecture:** This lecture will introduce course participants to the fundamental principles of measuring ocean colour from space. Apparent and inherent optical properties, and their connection to biogeochemical properties will be summarised. The lecture will also cover the basic characteristics of satellite ocean colour missions including spectral resolution, and the main processing steps needed between space-based measurements and validated geophysical products.

**Objectives of the lecture:**

OBJ-1: Understand the key parameters measured and derived from ocean colour radiometry

OBJ-2: Be aware of the variety of ocean colour missions and how they vary in terms of spatial, temporal, and spectral coverage.

OBJ-3: Gain an overview of the processing steps needed to derive geophysical variables from ocean colour data.

OBJ-4: Understand the basic principles of satellite validation

**Abstract:**

Ocean colour sensors measure light reflected from the ocean surface across (predominantly) the visible part of the electromagnetic spectrum. The colour of the ocean is intimately linked to its biogeophysical characteristics (e.g. chlorophyll-a or sediment concentrations) via the absorbing and scattering properties of these constituents. Exploiting ocean colour as measured from satellites necessitates an understanding of these characteristics and how the retrieve them from the data measured by the satellites at the top of the atmosphere. This lecture will introduce apparent and inherent optical properties, how they vary for different constituents, and how they can be extracted from the ocean colour signal, post, atmospheric correction. It will also cover the process of satellite validation including the concept of in situ fiducial reference measurements, and extract and analysis of matchups.

**Software tools used in this lecture:**

None

**Data sets used in this lecture:**

None

**Key papers for background reading:**

1. IOCCG (2006). Remote Sensing of Inherent Optical Properties: Fundamentals, Tests of Algorithms, and Applications. Lee, Z.-P. (ed.), Reports of the International Ocean-Colour Coordinating Group, No. 5, IOCCG, Dartmouth, Canada. https://ioccg.org/wp-content/uploads/2015/10/ioccg-report-05.pdf
2. Ocean colour matchup protocols for OLCI: https://user.eumetsat.int/s3/eup-strapi-media/Recommendations_for_Sentinel_3_OLCI_Ocean_Colour_product_validations_in_comparison_with_in_situ_measurements_Matchup_Protocols_V8_B_e6c62ce677.pdf

## 5.16. DERIVING GEOPHYSICAL INFORMATION FROM THE OCEAN COLOUR SIGNAL

**Date and time:** 17th December 2024, 16:50-17:10

**Lecturer:** Dr Hayley Evers-King (EUMETSAT) and Dr. Astrid Bracher (AWI)

**Aim of the lecture:** This interactive lecture will show how information from ocean colour sensors can be used to derive geophysical parameters. Building on the content of the previous lecture, participants will learn how to use a simple forward model to estimate the ocean colour signal produced from different oceanic conditions. They will also have the option to download and intercompare ocean colour products

**Objectives of the lecture:**

OBJ-1: Understand how geophysical constituents, and their absorbing and scattering properties, influence the ocean colour signal.

OBJ-2: Access ocean colour data from a current, medium resolution, mission – OLCI aboard Sentinel-3.

OBJ-3: Open data in a Jupyter Notebook environment, plot the standard chlorophyll-a products using appropriate flags. Observe and explain likely reasons for differences between the products.


### Abstract:

The utility of ocean colour data is derived from the relationship between the ocean colour signal and in-water constituents. Understanding how variability in biogeochemical properties of ocean waters influences the ocean colour signal is thus essential to exploiting it via the development of suitable algorithms. Models connecting the absorption and scattering properties of in water constitutes to the ocean colour signal, can be used to understand this link and develop empirical and semi-analytical algorithms, as well as providing input to modern AI or machine learning techniques. Inherent in its role in photosynthesis is the interaction between incoming light and the Chlorophyll-a pigment. It is this fundamental connection that links variability in chlorophyll concentration with the colour of the ocean, phytoplankton activity, and thus primary production in the world's oceans. Fundamental observations of the variability between more blue and more green regions of the ocean lead to the development of empirical algorithms to quantify this using radiometric measurements. These relationships still form much of the basis of open ocean chlorophyll-a quantification today. However, in complex waters, such as those with inputs from sediments, or under situations of extreme phytoplankton biomass, these simple relationships break down. This has led to the development of alternative algorithms, using different spectral measurements, and more advanced computational techniques. In this interactive lecture a Jupyter notebook will allow users to experiment with a simple forward model, whilst a second notebook will show how to access ocean colour data from OLCI aboard the Sentinel-3 satellites. The latter will show participants how to plot standard chlorophyll-a products, apply other simple empirical algorithms, provide guidance on suitability for regional applications, and provide links to more advanced workflows applying other algorithms.


### Software tools used in this lecture:

1. Jupyter Notebooks available from: https://gitlab.eumetsat.int/eumetlab/oceans/ocean-training/sensors/learn-olci
2. Participants should follow instructions for local installation provided in the README, or be comfortable using a Binder implementation.
3. Participants should conduct a fresh git pull/test Binder just before the lectures.

### Data sets used in this lecture:

1. Level-1 and 2 OLCI data from EUMETSAT.

2. Participants will need an eoportal account to access data from EUMETSAT – they can visit https://eoportal.eumetsat.int.

### Key papers for background reading:


1. IOCCG (2006). Remote Sensing of Inherent Optical Properties: Fundamentals, Tests of Algorithms, and Applications. Lee, Z.-P. (ed.), Reports of the International Ocean-Colour Coordinating Group, No. 5, IOCCG, Dartmouth, Canada. https://ioccg.org/wp-content/uploads/2015/10/ioccg-report-05.pdf
2. IOCCG (2000). Remote Sensing of Ocean Colour in Coastal, and Other Optically-Complex, Waters. Sathyendranath, S. (ed.), Reports of the International Ocean-Colour Coordinating Group, No. 3, IOCCG, Dartmouth, Canada. https://ioccg.org/wp-content/uploads/2015/10/ioccg-report-03.pdf


## 5.17. REGIONAL OCEAN COLOUR APPLICATIONS

**Date and time:** 17th December 2024, 17:30-17:50

**Lecturer:** Dr Hayley Evers-King (EUMETSAT) and Dr. Astrid Bracher (AWI)

**Aim of the lecture:** This lecture will cover fundamental aspects of applications of ocean colour data, with examples drawn from the Arctic, North Atlantic, and European Coastal Seas.

**Objectives of the lecture:**

OBJ-1: Learn about the diverse array of applications of ocean colour data.

OBJ-2: Understand the value of using ocean colour data synergistically with other data sets.

OBJ-3: Learn from regional examples of how biogeochemical measurements can be used to address socio-economic and environmental challenges in the region.

**Abstract:**


The Arctic and North Atlantic oceans are highly dynamic in terms of physical oceanography, and this has a concurrent impact on the biogeochemical characteristics of the region. Satellites offer both the temporal and spatial scales to observe these dynamics, as well as a suite of measurement methods to capture both the physical and biogeochemical dynamics. This lecture will cover a general background about the applications of ocean colour data, supported by examples from regional applications. This will include how data can be used in synergy to understand the drivers of biogeochemical variability and their role in the wider cycles of the Earth system, and how this can be used in applications ranging from fisheries and aquaculture management to marine spatial planning and climate change adaptation.

### Software tools used in this lecture:

None

### Data sets used in this lecture:

None

### Key papers for background reading:

1. IOCCG (2008). Why Ocean Colour? The Societal Benefits of Ocean-Colour Technology. Platt, T., Hoepffner, N., Stuart, V. and Brown, C. (eds.), Reports of the International Ocean-Colour Coordinating Group, No. 7, IOCCG, Dartmouth, Canada. https://ioccg.org/wp-content/uploads/2015/10/ioccg-report-07.pdf
2. IOCCG (2009). Remote Sensing in Fisheries and Aquaculture. Forget, M.-H., Stuart, V. and Platt, T. (eds.), Reports of the International Ocean-Colour Coordinating Group, No. 8, IOCCG, Dartmouth, Canada. https://ioccg.org/wp-content/uploads/2015/10/ioccg-report-08.pdf
3. https://www.sciencedirect.com/science/article/pii/S0272771422001676

## 5.18. IN SITU APPROACHES TO COMPLEMENT SATELLITE OCEAN COLOUR IN MARINE MICROBIAL RESEARCH

**Date and time:** 17 December 2025 17:30-18:15

**Lecturer:** Dr. Kat Morrissey (University of Capetown)

**Aim of the lecture:** At the end of this lecture, you should understand synergistic use of *in situ* and satellite data to gain a more comprehensive perspective on marine microbes and their role in oceanic processes.

### Objectives of the lecture:

OBJ-1: Understand in situ sampling methods for satellite ocean colour

OBJ-2: Understand the latest protocols for shipboard sampling, sample processing methodologies, and eventual data generation and integration

### Abstract:

The integration of in situ sampling methods with satellite ocean colour observations presents a powerful approach for advancing marine microbial research. This lecture will explore *in situ* techniques that are used to understand the distribution, abundance, and productivity of marine microbes. These methods can help complement and enhance the accuracy of satellite-derived data, leading to more reliable interpretations of marine microbial dynamics. Students will gain insights into the latest protocols for shipboard sampling, sample processing methodologies, and eventual data generation and integration. We will explore the synergistic use of *in situ* and satellite data to gain a more comprehensive perspective on marine microbes and their role in oceanic processes.

Software tools used in this lecture:

Exploration and handling of biological data (Using R studio)

**Data sets used in this lecture:**

None

**Key papers for background reading:**


1. Basedow, S.L., McKee, D., Lefering, I. et al. Remote sensing of zooplankton swarms. Sci Rep 9, 686 (2019). https://doi.org/10.1038/s41598-018-37129-x
2. Demarcq, H., Reygondeau, G., Alvain, S., Vantrepotte, V., 2012. Monitoring marinephytoplankton seasonality from space. Remote Sens. Environ. 117, 211–222.
3. Druon, JN., Hélaouët, P., Beaugrand, G. et al. Satellite-based indicator of zooplankton distribution for global monitoring. Sci Rep 9, 4732 (2019). https://doi.org/10.1038/s41598-019-41212-2
4. Grimes DJ, Ford TE, Colwell RR, Baker-Austin C, Martinez-Urtaza J, Subramaniam A, Capone DG. Viewing marine bacteria, their activity and response to environmental drivers from orbit: satellite remote sensing of bacteria. Microb Ecol. 2014 Apr;67(3):489-500. doi: 10.1007/s00248-013-0363-4. Epub 2014 Jan 30. PMID: 24477922; PMCID: PMC4058845.
5. Peter E Larsen, Nicole Scott, Anton F Post, Dawn Field, Rob Knight, Yuki Hamada, Jack A Gilbert, Satellite remote sensing data can be used to model marine microbial metabolite turnover, The ISME Journal, Volume


## 5.19. OCEAN FORECASTING: MODELS, DATA, ACCESS AND APPLICATIONS

**Date and time:** 7th January 2025, 16:30-18:15

**Lecturer:** Dr. Karina von Schuckmann (Mercator Ocean International)

**Aim of the lecture:** By the end of this lecture, you should understand modern-day operational oceanography and how the Copernicus Marine Service can assist your work during the OTC25.

**Objectives of the lecture:**

OBJ-1: Review Operational Oceanography

OBJ-2: Review the Copernicus Marine Service

OBJ-3: Explore tools available from CMEMS to support your OTC25 work

**Abstract:**

It is difficult to accurately estimate the importance of the ocean for humankind and animal life on our planet. Covering 70% of the Earth's surface, the ocean is the world's largest source of oxygen. It absorbs 50 times more carbon dioxide than the atmosphere. Climate is regulated by ocean heat transport, making our world a habitable place. For human beings, the ocean is also a source of food, economic resources, travel, and leisure

activities; the economic activities associated with the ocean are numerous and of crucial importance. These facts and figures highlight why operational ocean monitoring and forecasting can be considered a vital discipline.

Operational Oceanography, defined as the set of activities for the generation of products and services providing information on the marine and coastal environment, is based on two main pillars:

- The monitoring element focuses on the systematic and long-term routine measurements of oceans and atmosphere, and their rapid interpretation and dissemination.
- The prediction component uses ocean models to generate a variety of products: nowcasts (describing the present ocean state provided by analyses); forecasts (the future condition of the ocean) or hindcasts (the ocean's past states, provided by reanalysis).

The Copernicus Marine Service (CMEMS) ( marine.copernicus.eu) provides free, regular and systematic authoritative information on the state of the Blue (physical), White (sea ice) and Green (biogeochemical) ocean, on a global and regional scale. It is funded by the European Commission (EC) and implemented by Mercator Ocean International. It is designed to increase global ocean knowledge and boost the Blue Economy across all maritime sectors by providing free-of-charge state-of-the-art ocean data and information. It provides key inputs that support major EU and international policies and initiatives and can contribute to: combating pollution, marine protection, maritime safety and routing, sustainable use of ocean resources, developing marine energy resources, blue growth, climate monitoring, weather forecasting, and more. It also aims to increase awareness among the public by providing European and global citizens with information about ocean-related issues.

- Data: Free and open scientifically-assessed ocean data across the global ocean see https://marine.copernicus.eu/access-data
- Support and Expertise: Free and open manned-support office, resources, and training & workshops both on and offline
- Use Case Studies: see https://marine.copernicus.eu/services/use-cases
- Services: Free and open ocean literacy materials, events, ocean health news, Use Cases, resources to support Blue Market sectors, and interactive digital tools – see https://marine.copernicus.eu/services
- CMEMS E-learning tutorials: https://marine.copernicus.eu/services/user-learning-services/tutorials

### Software tools used in this lecture:

1. CMEMS visualisation: https://marine.copernicus.eu/access-data/ocean-visualisation-tools

**Data sets used in this lecture:**

1. https://marine.copernicus.eu/access-data

**Key papers for background reading:**

1. CMEMS E-learning tutorials: https://marine.copernicus.eu/services/user-learning-services/tutorials

## 5.20. MAKING OTC25 MEASUREMENTS AT SEA

**Date and time:** 27th January 2025 17:30-18:15

**Lecturer:** OTC25 Lecture Team

**Aim of the lecture:** To review how OTC25 instrumentation aboard the Statsraad Lehmkuhl will be used during OTC25

**Objectives of the lecture:**

OBJ-1: Understand how the instruments aboard the can be used in ocean research during the OTC25

**Abstract:**

This lecture will review how the instrumentation on board the Statsraad Lehmkuhl can be used in student projects during the voyage.

## 5.21. OCEAN INSTRUMENTS ABOARD THE STATSRAAD LEHNMKUHL

**Date and time:** 21st January 2025 16:30-18:15

**Lecturer:** Geir Pendersen, Institute of Marine Research, Norway

**Aim of the lecture:** To review the underway instrumentation aboard the Statsraad Lehmkuhl

**Objectives of the lecture:**

OBJ-1: Understand the underway instruments and the data that will be collected

Abstract:

This lecture will review the instrumentation on board the Statsraad Lehmkuhl and explain how the data will be collected and made available to Students during the voyage.

The following instrumentation is being installed on the ship to support science activities.

| Quantity | Sensor | Measurements at sea | Description | Link / specs | Installation |
|---|---|---|---|---|---|
| Permanent equipment - the backbone instrumentation | | | | | |
| 2 | Smart sensor | Continuous | WS700-UMB | https://www.lufft.com/products/compact-weather-sensors-293/ws700-umb-sm | Mast |
| 2 | Radar Precipitation Sensor | Continuous | WS100 | https://www.lufft.com/products/precipitation-sensors-287/ws100-radar-precipita | Mast |
| 2 | IR sensor for SST skin temperature measurements | Continuous | Apogee SI-421-SS | https://www.scaledinstruments.com/shop/apogee-instruments/infrared-radiome | Mast |
| 1 | Carousel (sensors, watersamplers) | Stations | SBE 32SC SUB COMPACT CAROUSEL - 12x2.5l | https://havforskningsinstituttet.sharepoint.com/:x:/r/teams/OneOcean2/Shared% | CTD Carousel |
| 1 | Winch for carousel | Stations | EIVA OceanEnviro | https://www.eiva.com/products/hardware/oceanenviro-winches | Deck |
| 1 | CTD - carousel | Stations | Seabird SBE19plus V2 | https://www.seabird.com/sbe-19plus-v2-seacat-profiler-ctd/product?id=607614 | CTD Carousel |
| 1 | Dissolved oxygen - carousel | Stations | SBE43 DO | https://www.seabird.com/sbe-43-dissolved-oxygen-sensor/product?id=607624 | CTD Carousel |
| 1 | ChlA/turbidity/backscatter - carousel | Stations | CHL-a & TURBIDITY ECO-FLNTU | https://www.seabird.com/eco-flntu/product?id=60762467722 | CTD Carousel |
| 1 | PAR - carousel | Stations | SATPAR PAR-LOG ICSW, | https://www.seabird.com/photosynthetically-active-radiation-par-sensor/product | CTD Carousel |
| 1 | PAR - carousel | Stations | SATPAR SURFACE/REFERENCE PAR | https://www.seabird.com/photosynthetically-active-radiation-par-sensor/product | CTD Carousel |
| 1 | pH - carousel | Stations | SBE18 pH | https://www.seabird.com/ph-sensors/sbe-18-ph-sensor/family?productCategory | CTD Carousel |
| 1 | ADCP - 300 kHz | Continuous | Kongsberg CP300 | https://www.kongsberg.com/discovery/ocean-science/ocean-science-transducers | Hull mounted |
| 1 | ADCP - 75 kHz | Continuous | Teledyne RDI Ocean Surveyor ADCP (75kHz) | https://www.teledynemarine.com/brands/rdi/ocean-surveyor-adcp | Hull mounted |
| 3 | Hydrophone hull mounted | Continuous | Ocean Sonics icListen HF | https://oceansonics.com/iclisten-hf-hydrophone/ | Hull mounted |
| 1 | SooGuard - Ferrybox | Continuous | AADI SOOGUARD Ferrybox system | https://www.aanderaa.com/media/pdfs/b188-sooguard-ferry-box-system.pdf | Water intake / below deck |
| 1 | *Conductivity, temperature - Ferrybox* | *Continuous* | *AADI 4319B* | *https://www.aanderaa.com/media/pdfs/TD263-Condcutivity-sensor-4319.pdf* | *Water intake / below deck* |
| 1 | *O2 - Ferrybox* | *Continuous* | *AADI 4835* | *https://www.aanderaa.com/oxygen-sensors* | *Water intake / below deck* |
| 1 | *Turbidity - Ferrybox* | *Continuous* | *AADI 4112* | *https://www.aanderaa.com/turbidity-sensor* | *Water intake / below deck* |
| 1 | *ChlA - Ferrybox* | *Continuous* | *Turner Designs Cyclops* | *https://www.turnerdesigns.com/cyclops-7f-submersible-fluorometer* | *Water intake / below deck* |
| 1 | *Phycoerythrin - Ferrybox* | *Continuous* | | | *Water intake / below deck* |
| 1 | Scientific Echosounder EK80 | Continuous | Kongsberg wideband scientific echosounder (WBT) | https://www.kongsberg.com/discovery/ocean-science/ek-family/ek80/ | Hull mounted / blister |
| 1 | *Kongsberg ES38/200 Combi C echosounder transducer* | *Continuous* | *38 (split-beam) and 200 kHz (single-beam) echosounder transducers* | https://www.kongsberg.com/discovery/ocean-science/ocean-science-transducers | Hull mounted / blister |
| 1 | *Kongsberg ES120-7C echosounder transducer* | *Continuous* | *120 kHz split-beam echosounder transducer* | https://www.kongsberg.com/discovery/fish-finding/fishery-split-beam-transducer | Hull mounted / blister |
| 1 | eDNA filtration | Manual samples | Manual water samples water intake + towed water sampler ("torpedo") | - | Water intake / lab |
| 1 | eDNA extraction | Manual samples | Biomeme Franklin qPCR, Biomeme M1 Cartrigde | https://shop.biomeme.com/franklin-real-time-pcr-thermocycler/ | |
| 1 | Microplastics filtration/analysis | Manual samples | Lab / water intake + particle sizes, number (more info comming) | Comming | Water intake / lab |
| 1 | CTD | At stations | Additional CTD / high res 100m (Xylem Castaway) | https://www.xylem.com/en-us/products--services/analytical-instruments-and-eq | Lowered |
| 2 | Fishing equipment | Manual samples | Specs | | Lowered |
| 1 | Net sampling | Manual samples | WP2 plankton net, mesh size of 180 micrometer | | Lowered |
| 3 | SeaAwarenes camera | Continuous | 2xKCC100, 1xKCC 200n | https://www.kongsberg.com/discovery/navigation-positioning/kongsberg-camera | Mast |
| 1 | PAR | Continuous | Quantum SQ-522 | https://www.apogeeinstruments.com/content/SQ-522.pdf | Mast |
| 1 | Ocean model | Continuous (downloaded data) | Mercator/Blue Insight (data downloaded and made accessible to crew and scientists | | - |
| 2 | TorpedDNA | Manual samples | eDNA sampler | | Towed |
| 2 | Freezers | Continous | Specs | | - |
| 1 | Data management and event logging | Continuous | KD Blue Insight for data storage, event logging, transmission of data, acces to data ombord | | - |

## 5.22. RELATIONSHIP BETWEEN OCEAN MATTER AND ITS OPTICAL PROPERTIES.

**Date and time:** 14 January 2025, 16:30-17:10

**Lecturer:** Emmanuel Boss (University of Maine, USA)

**Aim of the lecture:** By the end of the lecturer students should understand why light is used to study matter in aquatic environments.

**Objectives of the lecture:**

OBJ-1: Introduce the students to how matter interact with light (absorption, scattering and fluorescence).

OBJ-2: Introduce the students to how specific properties of matter (e.g. size, composition) affect absorption and scattering.

**Abstract:**

Light, electromagnetic energy near the visible part of the spectra, plays a major role in ocean biology and biogeochemistry (e.g. photosynthesis and photochemistry). In addition, the interaction of matter in the ocean with light provides means to detect the material and its underlying properties using measurements of optical properties. In this lecture I will introduce the students to the optical properties that are measured in the ocean and that affect the radiometry measured by satellites. We will then study how these optical properties vary as a function of the properties of ocean matter.

**Software tools used in this lecture:**

None

**Data sets used in this lecture:**

None

**Key papers for background reading:**

1. Ch 3-8 in Mobley's 'The Oceanic Optics Book', https://ioccg.org/wp-content/uploads/2022/01/mobley-oceanicopticsbook.pdf

## 5.23. HOW WE MEASURE THE OPTICAL PROPERTIES OF THE MATERIAL IN THE OCEAN.

**Date and time:** 14 January 2025, 17:30-18:15

**Lecturer:** Emmanuel Boss (University of Maine, USA)

**Aim of the lecture:** By the end of this lecture students should appreciate the efforts that need to be exerted to measure accurately optical properties of aquatic matter and, therefore, the necessity to always assess the quality of the measurements using independent methods (closure).

**Objectives of the lecture:**

OBJ-1: Introduce the sources of uncertainties associated with field and lab measurements of oceanic matter.

OBJ-2: Present several methods used to estimate specific optical properties of aquatic matter and associated uncertainties.

OBJ-3: Introduce the concept of closure – the only means we have to associate realistic uncertainties to our measurements of optical properties.

**Abstract:**

Measuring the optical properties of aquatic material is difficult. In the field, movement of the platform we measure from, contamination by materials we are not interested to measure (e.g. bubbles) and interaction between material and instrument all can cause bias in measurements. When we collect material in field to measure in the lab (e.g. filtration) we can also introduce biases. Finally, all the instrument we use to measure optical properties in the lab or ocean have limitations in their ability to measure the optical properties we are after. In this lecture we will discuss current methods to measure optical properties of aquatic materials and some of their advantages as well as their potential bias.

The above does not mean we should not pursue such measurements, but rather that we should always attempt to obtain other independent measurements that would help us assess the quality of our measurements (a process cold closure). Our saving grace is that

matter in the ocean varies several orders of magnitude in concentration. This fact alone means that even with large uncertainties, optical measurements can be very useful.

We will also cover Mobley's conservation of misery principle which state that: "what is easy to measure is hard to interpret" and the Sieracki's principle which states that in term of information: "with a finite amount of resources one can learn a lot on very little matter or learn little on a lot of material".

**Software tools used in this lecture:**

None

**Data sets used in this lecture:**

None

**Key papers for background reading:**

1. Ch 3-8 in Mobley's 'The Oceanic Optics Book', https://ioccg.org/wp-content/uploads/2022/01/mobley-oceanicopticsbook.pdf
2. IOCCG Protocol Series (2018). Inherent Optical Property Measurements and Protocols: Absorption Coefficient, Neeley, A. R. and Mannino, A. (eds.), IOCCG Ocean Optics and Biogeochemistry Protocols for Satellite Ocean Colour Sensor Validation, Volume 1.0, IOCCG, Dartmouth, NS, Canada. http://dx.doi.org/10.25607/OBP-119
3. IOCCG Protocol Series (2019). Beam Transmission and Attenuation Coefficients: Instruments, Characterization, Field Measurements and Data Analysis Protocols. Boss, E., Twardowski, M., McKee, D., inić, I. and Slade, W. IOCCG Ocean Optics and Biogeochemistry Protocols for Satellite Ocean Colour Sensor Validation, Volume 2.0, edited by A. Neeley and I. inić, IOCCG, Dartmouth, NS, Canada. http://dx.doi.org/10.25607/OBP-458

## 5.24. REMOTE SENSING IN THE OCEAN: BASIC PRINCIPLES AND APPLICATIONS OF UNDERWATER ACOUSTIC MEASUREMENTS.

**Date and time:** 28th January 2025 17:30-18:15

**Lecturer:** Roger Haagmans (ESA Academy)

**Aim of the lecture:** At the end of this lecture, you should understand the basic principles and applications of underwater acoustic measurements.

**Objectives of the lecture:**

OBJ-1: Understand how acoustic measurements for ocean science are made

OBJ-2: Interpret the ocean acoustic signals from shipboard measurements

**Abstract:**

This lecture is focusses on underwater acoustics and it's applications in quantitative and qualitative probing of the sea or ocean. The application of underwater acoustic systems shows many similarities with remote sensing from satellites. Instead of a satellite, a ship is the "platform" on which the acoustic measurement system is mounted. The location, speed, motion and noise of the ship need to be monitored in order to arrive at an adequate interpretation of the acoustic measurements. The big difference with satellite remote sensing is the use of sound instead of electromagnetic signals. So the propagation of sound in water is relates pressure changes and results in longitudinal waves. The characteristics of the medium sea water cause sound to propagate at different speed or in different direction depending on e.g. salinity and pressure changes along the path. Basic principles of underwater acoustics will be explained. Also examples of applications for quantitative and qualitative use in hydrography and ocean science will be shown. This introduction is aiming to provide a basis for understanding the on-board acoustic measurements.

### Software tools used in this lecture:

None

### Data sets used in this lecture:

None

### Key papers for background reading:


1. Hydrography – textbook, C. D. de Jong, G. Lachapelle, S. Skone, I. Elema, https://www.ucalgary.ca/engo_webdocs/SpecialPublications/Hydrography_2ndEdition_eBook_2010.pdf
2. Acoustic mapping of mixed layer depth, Christian Stranne, Larry Mayer, Martin Jakobsson, Elizabeth Weidner, Kevin Jerram, Thomas C. Weber, Leif G. Anderson, Johan Nilsson, Göran Björk, and Katarina Gårdfeldt. Ocean Sci., 14, 503–514, 2018, https://doi.org/10.5194/os-14-503-2018
3. Acoustic seafloor mapping, Rory Quinn, University of Ulster, 2012. https://rqmodules.weebly.com/uploads/1/9/4/8/19483873/acoustic_seafloor_mapping.pdf


*User experience workshop reports on Marine Acoustic System applications*


1. 2016 USA–Norway EK80 Workshop Report: Evaluation of a wideband echosounder for fisheries and marine ecosystem science, David A. Demer, Lars N. Andersen, Chris Bassett, Laurent Berger, Dezhang Chu, Jeff Condiotty, George R. Cutter Jr., Briony Hutton, Rolf Korneliussen, Naig Le Bouffant, Gavin Macaulay, William L. Michael, David Murfin, Armin Pobitzer, Josiah S. Renfree, Thomas S. Sessions, Kevin L. Stierhoff, Charles H. Thompson, ICES Cooperative Research Report, No. 336, April 2017. https://ices-library.figshare.com/articles/report/2016_USA_Norway_EK80_Workshop_Report_Evaluation_of_a_wideband_echosounder_for_fisheries_and_marine_ecosystem_science/19056584
2. Best Practices for Implementing Acoustic Technologies to Improve Reef Fish Ecosystem Surveys, Report from the 2017 GCFI Workshop, NOAA Technical Memorandum NMFS-F/SPO-192, April 2019. https://spo.nmfs.noaa.gov/sites/default/files/TM192.pdf

*Information on Simrad EK80 systems and ADCP aboard the Statsraad Lehmkuhl*

1. Simrad EK80 -Combining a scientific echo sounder with ADCP https://www.simrad.online/ek80/sales/ek80_adcp_ds_en_a4.pdf
2. Simrad EK Systems - https://www.sikuliaq.alaska.edu/ops/pdf/EK80_Datasheets_small.pdf

## 5.25. GRAVITY AND THE OCEAN

**Date and time:** 28th January 2025 16:30-17:10

**Lecturer:** Roger Haagmans (ESA Academy)

**Aim of the lecture:** At the end of this lecture, you should understand the different roles gravity field information can play in relation to ocean analysis

**Objectives of the lecture:**

OBJ-1: Understand static and dynamic gravity fields in relation to ocean science

OBJ-2: Interpret the ocean surface signals measured by gravity satellite missions

**Abstract:**

This lecture is focusses on the different roles gravity field information can play in relation to ocean analysis. The static gravity field represents the geoid which is the "sea level at rest". Ocean surface deviations from the geoid represent (near-)surface dynamic features. These also play an important role when combining ocean satellite measurements and tide gauge information to monitor sea level change. Time variations of the gravity field over the oceans relate to pressure changes in the atmospheric and water column. These can be use to get information on the ocean bottom pressure, and can contribute a better understanding of deeper ocean processes. The third category is again based upon a high resolution (static) gravity field. Through a simple assumed relationship between surface gravity and sea floor bathymetry, the latter can be derived. This is especially useful in areas where limited acoustic sounding information is available. The bathymetry plays an important role as a lower boundary of ocean models. This introduction is aiming to provide a basis for understanding the different roles of gravity in ocean science.

**Software tools used in this lecture:**

None

**Data sets used in this lecture:**

None

**Key papers for background reading:**

*Geoid and surface Mean Dynamic Topography/currents*

1. Rio, M.-H., S. Mulet, and N. Picot (2014), Beyond GOCE for the ocean circulation estimate: Synergetic use of altimetry, gravimetry, and in situ data provides new insight into geostrophic and Ekman currents, Geophys. Res. Lett., 41, 8918–8925, https://doi.org/10.1002/2014GL061773
2. Per Knudsen, Ole Andersen, Nikolai Maximenko, A new ocean mean dynamic topography model, derived from a combination of gravity, altimetry and drifter velocity. Advances in Space Research Volume 68, Issue 2, 15 July 2021, Pages 1090-1102 https://doi.org/10.1016/j.asr.2019.12.001
3. Morrow, R., Fu, LL., Rio, MH. et al. Ocean Circulation from Space. Surv Geophys 44, 1243–1286 (2023). https://doi.org/10.1007/s10712-023-09778-9
4. Gruber, T., Gerlach, C. and Haagmans, R.. "Intercontinental height datum connection with GOCE and GPS-levelling data" Journal of Geodetic Science, vol. 2, no. 4, 2012, pp. 270-280. https://doi.org/10.2478/v10156-012-0001-y

*Ocean Bottom Pressure and land ocean exchange*

1. Jessica K. Makowski, Don P. Chambers, Jennifer A. Bonin, Using ocean bottom pressure from the gravity recovery and climate experiment (GRACE) to estimate transport variability in the southern Indian Ocean. JGR Oceans https://doi.org/10.1002/2014JC010575
2. Chris W. Hughes, Joanne Williams, Adam Blaker, Andrew Coward, Vladimir Stepanov, A window on the deep ocean: The special value of ocean bottom pressure for monitoring the large-scale, deep-ocean circulation, Progress in Oceanography 161 (2018) 19–46, https://doi.org/10.1016/j.pocean.2018.01.011
3. Data and visualisation website at GFZ: https://gravis.gfz-potsdam.de/obp
4. J. T. Reager et al. ,A decade of sea level rise slowed by climate-driven hydrology.Science351,699-703(2016). https://doi.org/0.1126/science.aad8386
5. Bathymetry from satellite gravity
6. W. H. F. Smith, D. T. Sandwell and R. K. Raney, "Bathymetry from satellite altimetry: present and future," Proceedings of OCEANS 2005 MTS/IEEE, Washington, DC, USA, 2005, pp. 2586-2589 Vol. 3, https://doi.org/10.1109/OCEANS.2005.1640160
7. Adili Abulaitijiang, Ole Baltazar Andersen, David Sandwell, Improved Arctic Ocean Bathymetry Derived From DTU17 Gravity Model. Earth and Space Science, Volume6, Issue8, Pages 1336-1347, 2019, https://doi.org/10.1029/2018EA000502

## 5.26. OCEANS SATELLITE ALTIMETRY: THEORY AND APPLICATIONS

**Date and time:** February 4th 2025, 16:30-17:10

**Lecturer:** Dr. Alejandro Egido.

**Aim of the lecture:** By the end of this lecture, you should understand the principles of satellite radar altimetry and the implications of the different aspects involved in the retrieval of ocean geophysical parameters from satellite altimeter data.

### Objectives of the lecture

OBJ-1: Understand the satellite altimetry main concepts.

OBJ-2: Understand the retrieval process of geophysical parameters from satellite altimeter data.

OBJ-3: Understand the different aspects playing a role in the satellite altimeter measurement process.

OBJ-4: Understand the usefulness of satellite altimetry for the ocean from both an operational and scientific point of view.

## Abstract

Since its conception, satellite altimetry has been a major breakthrough in the field of ocean surface topography observations, enabling an improved understanding of oceanographic processes at global and regional scales, [International Altimetry Community, 2021].

Satellite altimeters carry on-board an active microwave instrument, known as radar, that transmits an electromagnetic pulse towards the Earth and records the echoes scattered of the ocean or other Earth's surfaces to measure the time elapsed between the transmission and reception of such pulse.

The time elapsed between transmission and reception of the radar signal is the key measurement in obtaining key geophysical parameters, such as the sea surface height (SSH), calculated as the difference between the position of the satellite on-orbit (with respect to an arbitrary point) and the measured range to the surface, [Chelton, et al., 2001].

However, achieving the measurement uncertainty needed for oceanographic studies -a few centimetres- from hundreds of kilometres is a major challenge. For that purpose, satellite altimeters incorporate precise orbit determination systems -to have an accurate estimation of the satellite's position in orbit- and microwave radiometers -to correct for atmospheric propagation delays introduced by the water vapor in the atmosphere-. In addition, other environmental conditions need to be accounted for and corrected -either from the altimeter data or models-, such is the case of ionospheric delays, inverse barometric pressure, tides, and sea state.

Indeed, the sea state is one of the biggest sources of uncertainty in the determination of SSH from a radar altimeter. When the altimeter pulse encounters the ocean surface, the presence of waves widens the reflected pulse according to the surface roughness. In fact, the scattered echo is the combination of multiple reflections from points on the surface, that add up together in a random manner, generating a multiplicative noise known as speckle. To be able to beat down the speckle, multiple pulses need to be averaged together, for that reason, radar altimeters transmit thousands of pulses per second that are combined to get the final radar waveform.

In the end, to retrieve precise measurements from these complicated echoes, a model needs to be fitted to the recorded echo in a process called retracking, that adjusts some

parameters in an iterative process to minimize the error between the measured and the modelled waveform. For the open ocean, those parameters typically comprise the sea surface height, the significant wave height, and the waveform power, which can be ultimately linked to the wind speed.

Satellite altimetry is now a key element in operational systems covering a wide range of applications, from weather and hurricane forecasting to wind and wave forecasting for early warning systems for safety at sea. In addition, the current satellite constellation provides information that are critical for climate projection studies as it is the main source of information for ocean dynamics and ocean circulation at global scale, and a key element in maintaining the sea level geodetic record.

**Software tools used in this lecture:**

None

**Data sets used in this lecture:**

None

**Key papers for background reading:**

1. International Altimetry Community, 2021: Altimetry for the future: Building on 25 years of progress, Advances in Space Research, Volume 68, Issue 2, 2021, Pages 319-363, https://doi.org/10.1016/j.asr.2021.01.022.
2. Dudley B. Chelton, John C. Ries, Bruce J. Haines, Lee-Lueng Fu, Philip S. Callahan, Chapter 1 Satellite Altimetry, Editor(s): Lee-Lueng Fu, Anny Cazenave, International Geophysics, Academic Press, Volume 69, 2001, https://doi.org/10.1016/S0074-6142(01)80146-7.

## 5.27. ESTIMATES OF OCEAN CIRCULATION FOR SATELLITE ALTIMETRY

**Date and time:** 11th February 2024 16:30-16:50

**Lecturer:** Dr. Marie Helene Rio (ESA)

**Aim of the lecture:** This lecture aims at explaining how to get from the along-track altimeter Sea Level Anomalies to gridded maps of the geostrophic component of the ocean circulation.

**Objectives of the lecture:**

OBJ-1: Get acquainted with the different mapping procedures allowing to get gridded maps of altimeter sea level anomalies from the along-track information.

OBJ-2: Understand the importance of the Mean Dynamic Topography to get from altimeter Sea Level Anomalies to Absolute Dynamic Topography, understand how it can be calculated from the combination of altimetry, in-situ and geoid measurements

OBJ-3: Understand how ocean surface currents may be derived from altimeter absolute dynamic topography and understand the strengths and limitations of this approach.

**Abstract:** Ocean surface currents are a key component of the Earth system. By transporting momentum, heat, salt, and tracers over large distances they regulate both the local and large-scale climate conditions and they contribute to the Lagrangian displacement of floating material, ranging from living resources to marine pollution. Consequently, in the last decade, a growing demand has emerged for accurate estimates of spatial and temporal current variations in the open ocean and in coastal waters at high resolution (<5 km). Ocean surface currents can be measured from in-situ platforms. However, the basic requirements (global coverage and high spatio-temporal resolution) can be achieved only from space.

Altimetry, by providing global, accurate and repetitive measurements of the Sea Surface Height (SSH), has been by far the most exploited system for the study of the ocean surface currents variability over the last 30 years. This is due to the fact that, as suggested by observations and scaling arguments, flow in the ocean interior (away from the boundary layers) and away from the equator is to the first order in geostrophic balance, which means that the ocean surface velocity field can be readily obtained from the gradients of the Absolute Dynamic Topography (ADT, i.e. the sea level above the geoid).

A key reference surface needed to reconstruct the ocean absolute dynamic topography from the sea level anomalies is the ocean Mean Dynamic Topography (MDT). The MDT is now known to centimetre accuracy at 100 km resolution through combined use of state-of-the-art mean sea surface (MSS) and GOCE (Gravity field and Ocean Circulation Experiment) data, at least in open ocean regions and away from coastal and ice-covered areas. The use of additional information from in-situ oceanographic measurements (drifting buoy velocities and hydrographic profiles) allows the MDT to be refined to resolve scales down to 30–50 km (Maximenko et al., 2009; Rio et al., 2014; Mulet et al, 2021).

Another aspect of the altimeter observation system is that measures are performed along-track. In order to obtain gridded map of altimeter-derived geostrophic currents the MDT is usually added to gridded maps of SLA, obtained combining along-track SLA from multiple altimeter missions. Different gridded procedures exist which will be introduced (LeTraon et al, 1999; Ubelmann et al, 2015; LeGuillou et al, 2021a, 2021b). The effective resolution of the SLA grid depends both on the number of satellites in the altimeter constellation and on the prescribed mapping scales. Ballarotta et al. (2019) found that multi-mission altimeter maps based on three satellites (available 70% of the time over the period 1993–2017) resolve mesoscale structures ranging from 100 km wavelength at high latitude to 800 km wavelength in the equatorial band over 4 weeks timescales. ESA

Ocean surface currents are then derived from the gridded maps of absolute dynamic topography using the geostrophic approximation. Considering the expected spatial scales of geostrophic structures in the ocean, that range from 200 km at the equator to 10-20km at high latitudes (Chelton et al, 1998), the mapping capability of present altimeter constellations fails at resolving the full geostrophic flow at mid to high latitudes. In addition, the geostrophic currents are just one component of the ocean total surface currents: other components include the Ekman currents that is set-up by the wind field, the tidal currents and a number of other ageostrophic (i.e. that differ from geostrophy) currents. The altimeter derived ocean currents therefore need to be further improved. This can be done by using information from other spaceborne, or in-situ instruments, as will be explained in LA7.

### Software tools used in this lecture:

None

### Data sets used in this lecture:

None

### Key papers for background reading:


1. Ballarotta, M., Ubelmann, C., Pujol, M.-I., Taburet, G., Fournier, F., Legeais, J.-F., Faugère, Y., Delepoulle, A., Chelton, D., Dibarboure, G., and Picot, N.: On the resolutions of ocean altimetry maps, Ocean Sci., 15, 1091–1109, https://doi.org/10.5194/os-15-1091-2019, 2019.
2. Chelton, D. B., deSzoeke R. A. , Schlax M. G. , El Naggar K. , and Siwertz N. , 1998: Geographical variability of the first baroclinic Rossby radius of deformation. J. Phys. Oceanogr.,28,433–460, doi:10.1175/1520-0485(1998)028<0433:GVOTFB>2.0.CO;2.
3. Le Guillou, F., Metref, S., Cosme, E., Ubelmann, C., Ballarotta, M., Le Sommer, J., & Verron, J. (2021a). Mapping Altimetry in the Forthcoming SWOT Era by Back-and-Forth Nudging a One-Layer Quasigeostrophic Model, Journal of Atmospheric and Oceanic Technology, 38(4), 697-710.
4. Le Guillou, F., Lahaye, N., Ubelmann, C., Metref, S., Cosme, E., Ponte, A., et al. (2021b). Joint estimation of balanced motions and internal tides from future wide-swath altimetry. Journal of Advances in Modeling Earth Systems, 13, e2021MS002613. https://doi. org/10.1029/2021MS002613
5. Le Traon, P.-Y., and Dibarboure G. , 1999: Mesoscale mapping capabilities of multiple-satellite altimeter missions. J. Atmos. Oceanic Technol., 16, 1208–1223, doi:10.1175/1520-0426(1999)016<1208:MMCOMS>2.0.CO;2.
6. Maximenko, N., Niiler, P., Centurioni, L., Rio,M.-H.,Melnichenko, O., Chambers, D., et al. (2009). Mean dynamic topography of the ocean derived from satellite and drifting buoy data using three different techniques. J. Atmos. Ocean. Technol. 26, 1910–1919. doi: 10.1175/2009JTECHO672.1
7. Mulet, S., Rio, M.-H., Etienne, H., Artana, C., Can, M., Dibarboure, G., Feng, H., Husson, R., Picot, N., Provost, C., and Strub, P. T.: The new CNES-CLS18 global mean dynamic topography, Ocean Sci., 17, 789–808, https://doi.org/10.5194/os-17-789-2021, 2021.
8. Rio, M.-H. and F. Hernandez (2004): "A Mean Dynamic Topography computed over the world ocean from altimetry, in-situ measurements and a geoid model." Journal of Geophysical Research 109(C12).

9. Ubelmann, C., Klein, P., & Fu, L. (2015). Dynamic Interpolation of Sea Surface Height and Potential Applications for Future High-Resolution Altimetry Mapping, Journal of Atmospheric and Oceanic Technology, 32(1), 177-184. Retrieved Sep 8, 2022, from https://journals.ametsoc.org/view/journals/atot/32/1/jtech-d-14-00152_1.xml
10. Villas Bôas AB, Ardhuin F, Ayet A, Bourassa MA, Brandt P, Chapron B, Cornuelle BD, Farrar JT, Fewings MR, Fox-Kemper B, Gille ST, Gommenginger C, Heimbach P, Hell MC, Li Q, Mazloff MR, Merrifield ST, Mouche A, Rio MH, Rodriguez E, Shutler JD, Subramanian AC, Terrill EJ, Tsamados M, Ubelmann C and van Sebille E (2019) Integrated Observations of Global Surface Winds, Currents, and Waves: Requirements and Challenges for the Next Decade. Front. Mar. Sci. 6:425. doi: 10.3389/fmars.2019.00425

## 5.28. JUPYTER NOTEBOOK ON GEOSTROPHIC SURFACE CURRENT ESTIMATION FROM ALTIMETER SEA SURFACE HEIGHT

**Date and time:** 4th February 2024 17:50-18:15

**Lecturer:** Dr. Lucile Gaultier (ODL)

**Aim of the lecture:** This lecture aims at computing geostrophic current from gridded sea surface height using SEAScope tool

**Objectives of the lecture:**

OBJ-1: Apply the geostrophic balance and understand the strengths and limitation of the hypothesis

OBJ-2: Learn to extract data from SEAScope and analyse them on a python notebook

**Abstract:** In this lecture we will learn to draw shapes using SEAScope tool and export selected data. The exported data will be analyzed using a python notebook. We will learn to get data from SEAScope and export it back to visualize them.

As a practical, we will derive geostrophic current from CMEMS mapped SSH. The computed geostrophic currents will be compared with CMEMS geostrophic current as well as the total currents and we will discuss the differences in different the North Atlantic region and in the Mediterranean Sea.

**Software tools used in this lecture**

The Ocean Data Laboratory SEAScope system:https://seascope.oceandatalab.com

**Data sets used in this lecture:**

Provided SEAScope compatible files (IDF Netcdf)

**Key papers for background reading:**

None

## 5.29. REGIONAL SEA-LEVEL VARIABILITY AND BUDGET: A FOCUS ON THE NORDIC HIGH LATITUDES

**Date and time:** 4th February 2025, 17:30-18:15

**Lecturer:** Antonio Bonaduce (NERSC)

**Aim of the lecture:** By the end of this lecture, you should understand methods of estimation of regional sea-level components of variability from remote-sensing (different satellite altimetry concepts, gravimetry), in-situ (tide-gauge, hydrographic data) and ocean models used for operational services and climate studies

**Objectives of the lecture:**

OBJ-1: to review of the techniques estimation of regional sea-level components of variability.

OBJ-2: to prepare for the application of hydrographic data collected during the OTC25 "at-sea component" will also support the intercomparison between sea-level budget components derived from remote sensing and in-situ data.

**Abstract:**

Sea level change, an important indicator of climate change[1], integrates the response of several components of the Earth's system (ocean, atmosphere, cryosphere and hydrosphere) to natural and anthropogenic forcing[2]. Estimating sea-level rise is one of the most important scientific issues, with a large societal benefit and impact[3–8]. Sea level rise during the 21st century[9] is expected to be larger than during the 20th century even if greenhouse gas emissions stopped now due to the larger thermal inertia of the ocean compared to the atmosphere[10]. At the global scale, sea level rise is mostly related to the expansion of water masses due to density variations (steric effect) and to the increase of freshwater due to ice-sheet and glacier melting, and redistribution of the water cycle between different Earth system components[11]. In comparison, regional sea level changes depend mostly on oceanic transports of heat, salt, and water masses among different basins[12]. Understanding the relevant underlying mechanisms related to regional sea level change is the key to reduce uncertainties, in particular, for regions sensitive to climate change. The warming of the Arctic has been four times faster than the rest of the globe [13], and the thermal expansion associated with it can influence the sea level of the region. Different drivers can have leading contributions to sea level trends in the Arctic, such as halosteric sea level change dominating the trend of Beaufort Gyre, and the combination of thermosteric sea-level and ocean mass change effects largely influencing the trend in Nordic Seas[14]. The variability of the sea-level trend combined with the reduced observing capabilities and shortcomings of the observing system networks at the Nordic high

latitudes represent challenges and large sources of uncertainties affecting the sea-level budget closure in the Nordic Seas and Arctic Ocean.

The lecture will focus on the methods of estimation of regional sea-level components of variability from remote-sensing (different satellite altimetry concepts, gravimetry), in-situ (tide-gauge, hydrographic data) and ocean models used for operational services and climate studies. The hydrographic data collected during the OTC25 "at-sea component" will also support the intercomparison between sea-level budget components derived from remote sensing and in-situ data, as well as the validation of numerical models.

### Software tools used in this lecture:

Hands on the components of the sea-level budget! The practical session will focus on the optimal use of remote sensing, in-situ measurements, and numerical model data for assessing regional sea-level variability, leveraging the exceptional ocean monitoring resources provided by the Copernicus Programme. Earth observations, in-situ data, and model outputs will be collocated to evaluate the primary contributors to sea-level trends in the Nordic Seas and Arctic region. The session will be dynamically designed to accommodate the specific regions of interest to the participants.

A dedicated Jupyter notebook will be developed, and visualization tools such as SEAScope and Syntool will be explored to enhance participants' engagement with Earth observations, in-situ data, and numerical model outputs.

### Data sets used in this lecture:

None

### Key papers for background reading:


1. Oppenheimer, M., B.C. Glavovic , J. Hinkel, R. van de Wal, A.K. Magnan, A. Abd-Elgawad, R. Cai, M. Cifuentes-Jara, R.M. DeConto, T. Ghosh, J. Hay, F. Isla, B. Marzeion, B. Meyssignac, and Z. Sebesvari. IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. in The Ocean and Cryosphere in a Changing Climate: Special Report of the Intergovernmental Panel on Climate Change (Cambridge University Press, 2022). doi:10.1017/9781009157964.
2. Horwath, M. et al. Global sea-level budget and ocean-mass budget, with a focus on advanced data products and uncertainty characterisation. Earth Syst. Sci. Data 14, 411–447 (2022).
3. Bonaduce, A., Pinardi, N., Oddo, P., Spada, G. & Larnicol, G. Sea-level variability in the Mediterranean Sea from altimetry and tide gauges. Clim. Dyn. 47, 2851–2866 (2016).
4. Bonaduce, A., Staneva, J., Grayek, S., Bidlot, J.-R. & Breivik, Ø. Sea-state contributions to sea-level variability in the European Seas. Ocean Dyn. 70, 1547–1569 (2020).
5. Gregory, J. M. et al. Concepts and Terminology for Sea Level: Mean, Variability and Change, Both Local and Global. Surv. Geophys. 40, 1251–1289 (2019).
6. Mangini, F., Chafik, L., Bonaduce, A., Bertino, L. & Nilsen, J. E. Ø. Sea-level variability and change along the Norwegian coast between 2003 and 2018 from satellite altimetry, tide gauges, and hydrography. Ocean Sci. 18, 331–359 (2022).

7. Mangini, F., Bonaduce, A., Chafik, L., Raj, R. & Bertino, L. Detection and attribution of intra-annual mass component of sea-level variations along the Norwegian coast. Sci. Rep. 13, 15334 (2023).
8. Kemgang Ghomsi, F. E. et al. Sea level variability in Gulf of Guinea from satellite altimetry. Sci. Rep. 14, 4759 (2024).
9. Fox-Kemper, B., H.T. Hewitt, C. Xiao, G. Aðalgeirsdóttir, S.S. Drijfhout, T.L. Edwards, N.R. Golledge, M. Hemer, R.E. Kopp, G. Krinner, A. Mix, D. Notz, S. Nowicki, I.S. Nurhati, L. Ruiz, J.-B. Sallée, A.B.A. Slangen, and Y. Yu. Ocean, Cryosphere, and Sea Level Change. in Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (ed. Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou) (Cambridge University Press, 2023). doi:10.1017/9781009157896.
10. Hu, A. & Bates, S. C. Internal climate variability and projected future regional steric and dynamic sea level rise. Nat. Commun. 9, 1068 (2018).
11. Storto, A., Bonaduce, A., Feng, X. & Yang, C. Steric Sea Level Changes from Ocean Reanalyses at Global and Regional Scales. Water 11, 1987 (2019).
12. Stammer, D., Cazenave, A., Ponte, R. M. & Tamisiea, M. E. Causes for Contemporary Regional Sea Level Changes. Annu. Rev. Mar. Sci. 5, 21–46 (2013).
13. Rantanen, M. et al. The Arctic has warmed nearly four times faster than the globe since 1979. Commun. Earth Environ. 3, 1–10 (2022).
14. Raj, R. P. et al. Arctic Sea Level Budget Assessment during the GRACE/Argo Time Period. Remote Sens. 12, 2837 (2020).

## 5.30. ADVANCED TECHNIQUES FOR MAPPING SEA SURFACE HEIGHT (SSH) FROM SPACE

**Date and time:** 11th Februrary 2025 16:50-17:10

**Lecturer:** Florian Le Guillou (DATALAS, France)

**Aim of the lecture:** to review the different experimental strategies for mapping Sea Surface Height (SSH) at high resolution.

**Objectives of the lecture:**

OBJ-1: Understand the physical constraints on SST mapping and techniques to address these including deep learning

OBJ-2: Explore synergies with other observed variables from space, such as Sea Surface Temperature, Salinity, or Ocean Colour

**Abstract:**

Global precise measurements of sea surface height (SSH), both alone and in combination with other space-borne or in situ data, are now systematically used to identify,

characterize, and track mesoscale eddies, diagnose ocean heat transport, provide insights into ocean circulation at the surface and at depth, and understand the dynamical coupling between the atmosphere and the ocean. These SSH satellite observations are irregularly distributed in space and time. Many scientific and operational applications, such as the reconstruction of global geostrophic currents, rely on interpolation techniques to provide gap-free, regularly-sampled SSH maps by combining data from several nadir-looking altimeters.

Today, operational SSH gridded products capture features at scales larger than 150 km at mid-latitudes, which greatly limits our understanding of the upper dynamic processes at short mesoscales and sub-mesoscales. Mainly motivated by the recently launched CNES/NASA SWOT mission and the upcoming ESA S3NG-T mission, the ocean community is working hard to improve the space-time resolutions of the SSH maps.

In this lecture, we will review the different experimental strategies for mapping SSH at high resolution. We will detail techniques based on: (1) physical constraints, (2) Deep Learning, and (3) synergies with other observed variables from space, such as Sea Surface Temperature, Salinity, or Ocean Colour.

### Software tools used in this lecture:

We will use OVL Portal and SEAScope with Python Notebooks.

### Data sets used in this lecture:

Various satellite altimeter, ocean colour and SST data sets.

### Key papers for background reading:


1. Archambault, T., Charantonis, A., Béréziat, D., Mejia, C., and Thiria, S.: Sea surface height super-resolution using high resolution sea surface temperature with a subpixel convolutional residual network, Environmental Data Science, 1, e26, https://doi.org/10.1017/eds.2022.28, 2022.
2. 4DVarNet-SSH: end-to-end learning of variational interpolation schemes for nadir and wide-swath satellite altimetry, Geoscientific Model Development, 16, 2119–2147, https://doi.org/10.5194/gmd-16-2119-2023, 2023.
3. Le Guillou, F., Gaultier, L., Ballarotta, M., Metref, S., Ubelmann, C., Cosme, E., and Rio, M.-H.: Regional mapping of energetic short mesoscale ocean dynamics from altimetry: performances from real observations, Ocean Science, 19, 1517–1527, https://doi.org/10.5194/os-19-1517-2023, 2023.
4. Martin, S. A., Manucharyan, G. E., and Klein, P.: Synthesizing Sea Surface Temperature and Satellite Altimetry Observations Using Deep Learning Improves the Accuracy and Resolution of Gridded Sea Surface Height Anomalies, Journal of Advances in Modeling Earth Systems, 15, e2022MS003 589, https://doi.org/https://doi.org/10.1029/2022MS003589, 2023.
5. Wilkin, J. L., Bowen, M. M., and Emery, W. J.: Mapping mesoscale currents by optimal interpolation of satellite radiometer and altimeter data, Ocean Dynamics, 52, 95–103, https://api.semanticscholar.org/CorpusID:15584872, 2002.

## 5.31. SATELLITE ALTIMETRY IN SYNERGY WITH OTHER MEASUREMENTS

**Date and time:** Tuesday 4th February 2025 17:30-18:15

**Lecturer:** Dr. Marie Helene Rio (ESA)

**Aim of the lecture:** This lecture builds on and expands Lecture LB5 on Ocean circulation estimation from altimetry. As highlighted during LB5, the altimeter observing system presents two major limitations for the monitoring of the ocean surface currents: only the geostrophic component of the currents can be derived, and in some areas, only for a limited range of the spatial scales spectra. By the end of this lecture, you should have an overall understanding of how altimeter data can be used in synergy with other space and in-situ measurements to obtain the much needed, more realistic ocean surface currents, and also get information about the 3D structure of the ocean circulation.

**Objectives of the lecture:**

*OBJ-1: Access information about how ocean variables measured from space by different sensors are linked to ocean surface currents (Sea Surface Temperature, Salinity, Ocean Colour, surface roughness). For each sensor understand the strength and the limitations of the use of the different variables to estimate ocean surface currents.*

*OBJ-2: Understand the synergy between the different space and in-situ measurements and how it can be used to get refined information about ocean surface currents.*

*OBj-3: Get introduced on how such information (altimetry together with other space measurements and in-situ data) can also be used to estimate the 3D ocean circulation.*

**Abstract:**

At the moment there is no satellite observing system that provides direct observations of the ocean surface currents. However, a large variety of active and passive remote-sensing instruments have been put into orbit in the last few decades providing continuous, global information about the ocean. This includes altimeters, scatterometers, Synthetic Aperture Radars (SAR), imaging radiometers operating at different wavelengths, spectrometers. Estimates of the surface current can be retrieved by transformation of these satellite-measured quantities based on a range of assumptions, feature tracking methods and empirical based retrieval algorithms.

As discussed in LB5, the altimeter observing system presents two major limitations for the monitoring of the ocean surface currents: only the geostrophic component of the currents can be derived, and in some areas, only for a limited range of the spatial scales spectra. In

order to obtain more realistic ocean surface currents, synergy with other space and in-situ measurements is needed.

Among the satellite observing systems that provides information about the ocean currents, excellent results have been achieved using the Doppler anomaly of satellite SAR instruments (Chapron et al, 2005, Moiseev et al, 2022). In that case, total surface currents can be estimated locally at 0.1 to 1km resolution but a significant limitation to the technique is that only currents in one direction can be estimated. On the other hand, in the last two decades, information on tracer distribution at the ocean surface as Sea Surface Temperature (SST), Ocean Colour (OC), and even more recently Sea Surface Salinity, has hugely increased thanks to the availability of several imaging radiometers/spectrometers. Their resolution goes from hundreds of meters to kilometres and various ocean patterns and signatures, such as frontal zones, filaments and spiralling eddies, often manifest in infrared based SST variability and Ocean colour fields, which are directly linked to ocean currents advection. Accordingly, the use of tracer information to estimate surface currents, as a complement to altimetry, has become a very dynamic research domain in the last two decades. Different methodologies can be found in the literature, including the Maximum Cross Correlation method (MCC, Emery et al, 1986), the effective Surface Quasi Geostrophy framework (e.g., Isern-Fontanet et al., 2006; González-Haro et al., 2016), and inversion of the SST conservation equation (e.g., Rio and Santoleri, 2018; Ciani et al, 2021).

In-situ measurements are also key information to be used in synergy with altimeter and other space-borne instruments to improve the retrieval of ocean currents. For instance, key information can be obtained from the use of in-situ drifting buoy velocities. Those velocities represent the total currents at the drifter drogue's depth (usually 15m), therefore including the geostrophic component, the Ekman currents, the inertial currents, and other high frequency ageostrophic currents. Several studies have provided empirical estimates of the Ekman currents from the combination of altimetry and is-situ drifter data, together with the knowledge of the wind field (Rio et al, 2014; Bonjean et al, 2002; Sudre et al, 2013). The estimated Ekman currents can then be added to the altimeter-derived geostrophic current to obtain an improved estimate of the ocean surface currents. Recent work from (Ubelmann et al, in preparation) have extended the use of the drifter information to estimate the inertial component of the current. The geostrophic part of the drifting buoy velocity can also be used to improve the spatio-temporal scales of the altimeter geostrophic current (Mulet et al, 2021). Other in-situ measurements that provide useful information to improve the altimeter derived currents, in particular in coastal areas, include HF radar, and AIS (Automated Information System) data information (LeGoff et al, 2021).

Finally, using altimetry in synergy with in-situ measurements of Temperature and Salinity has proved to be very useful to reconstruct the 3D velocity field. Different approaches have been developed in the recent years (Mulet et al, 2012; Buongiorno-Nardelli et al, 2020) that will be introduced.

### Software tools used in this lecture:

N/A

### Data sets used in this lecture:

N/A

### Key papers for background reading:


1. Ocean Circulation and Climate. Chapter 4. Remote Sensing of the Global Ocean Circulation. Book. Academic press edition (22 octobre 2013) Lee-Lueng Fu and Rosemary Morrow.
2. Bonjean, F., and Lagerloef, G. S. (2002). Diagnostic model and analysis of the surface currents in the tropical Pacific Ocean. J. Phys. Oceanogr. 32, 2938–2954. doi: 10.1175/1520-0485(2002)032<2938:DMAAOT>2.0.CO;
3. Buongiorno Nardelli, B. 2020: A Multi-Year Timeseries of Observation-Based 3D Horizontal and Vertical Quasi-Geostrophic Global Ocean Currents. Earth Syst. Sci. Data 2020, No. 12, 1711–1723. https://doi.org/10.5194/essd-12-1711-2020.
4. Chapron, B., Collard, F. & Ardhuin, F., (2005). Direct measurements of ocean surface velocity from space: Interpretation and validation. Journal of Geophysical Research -- Oceans, 110(C9), p.7008–+.
5. Ciani, D.; Charles, E.; Buongiorno Nardelli, B.; Rio, M.-H.; Santoleri, R. Ocean Currents Reconstruction from a Combination of Altimeter and Ocean Colour Data: A Feasibility Study. Remote Sens. 2021, 13, 2389. https://doi.org/10.3390/rs13122389
6. Emery, W. J., Thomas, A. C., Collins, M. J., Crawford, W. R. and Mackas, D. L., (1986). An objective method for computing advective surface velocities from sequential infrared satellite images. J. Geophysical Res., 91, 12 865-12 878.
7. González-Haro, C., Autret, E., Isern-Fontanet, J., Tandeo, P., and Garello, R. (2016). "Ocean surface current reconstruction: on the transfer function between infrared SST and along-track altimeter observations," in OCEANS 2016 MTS/IEEE Monterey (Monterey, CA: IEEE), 1–5.
8. Isern-Fontanet, J., Chapron, B., Lapeyre, G., Klein, P. (2006), Potential use of microwave Sea Surface Temperatures for the estimation of ocean currents. Geophys. Res. Lett. 33, L24608, doi:10.1029/2006GL027801.
9. Le Goff, C., Boussidi, B., Mironov, A., Guichoux, Y., Zhen, Y., Tandeo, P., et al. (2021). Monitoring the greater Agulhas Current with AIS data information. Journal of Geophysical Research: Oceans, 126, e2021JC017228. https://doi.org/10.1029/2021JC017228
10. Le Traon, P.Y. and G. Dibarboure, (2002), Velocity mapping capabilities of present and future altimeter missions: the role of high frequency signals. J. Atm. Ocean Tech., 19, 2077-2088.
11. Moiseev, A., Johannessen, J. A., & Johnsen, H. (2022). Towards retrieving reliable ocean surface currents in the coastal zone from the Sentinel-1 Doppler shift observations. Journal of Geophysical Research: Oceans, 127, e2021JC018201. https://doi.org/10.1029/2021JC018201
12. Mulet, S., Rio, M.-H., Mignot, A., Guinehut, S., and Morrow, R.: A new estimate of the global 3D geostrophic ocean circulation based on satellite data and in-situ measurements, Deep-Sea Res. Pt. II, 77–80, 70–81, https://doi.org/10.1016/j.dsr2.2012.04.012, 2012.

13. Mulet, S., H Etienne, M Ballarotta, Y Faugere, Rio, M.-H., G Dibarboure, N Picot, 2021 : Synergy between surface drifters and altimetry to increase the accuracy of sea level anomaly and geostrophic current maps in the Gulf of Mexico. Advances in Space Research 68 (2), 420-431
14. Rio, M.-H., S. Mulet, and N. Picot (2014), Beyond GOCE for the ocean circulation estimate: Synergetic use of altimetry, gravimetry, and in situ data provides new insight into geostrophic and Ekman currents, Geophys. Res. Lett., 41, doi:10.1002/2014GL061773.
15. Rio, M.-H., Santoleri, 2018: Improved global surface currents from the merging of altimetry and Sea Surface Temperature data, Remote Sensing of Environment, Volume 216,2018, Pages 770-785, ISSN 0034-4257, https://doi.org/10.1016/j.rse.2018.06.003.
16. Sudre, J., Maes, C., and Garçon, V. (2013). On the global estimates of geostrophic and Ekman surface currents. Limnol. Oceanogr. Fluids Environ. 3, 1–20. doi: 10.1215/21573689-2071927.

## 5.32. UPPER DYNAMIC SYNERGIES: SYNOPTIC CHART ANALYSIS AND VELOCITY PRODUCTS INTERCOMPARISON

**Date and time:** Tuesday 11th February 2025 17:50-18:15

**Lecturer:** Dr. Lucile Gaultier (ODL)

**Aim of the lecture:** Using OVL web portal drawing capabilities, you will learn to draw dynamical structures such as eddies and fronts from various observations (SST, Chlorophyll, SAR roughness) and compare them with surface current derived from observations or from models

**Objectives of the lecture:**

OBJ-1: Learn to use Syntool online portal drawing capabilities

OBJ-2: Learn to use in synergy various satellite observation to better understand the upper ocean dynamics.

**Abstract:**

In this lecture we will learn to draw fronts and eddies using the OVL web portal drawing capabilities. We will also learn how to import and export shapes in various formats as well as share them using SEAShot tool.

As a practical we will draw a synoptic chart using Sentinel-3 SLSTR SST and Sentinel-3 OLCI Chloropyll-a remote sensing observation in the North Atlantic region.

We will compare the position / presence of eddies and frontal structures manually drawn with the eddies and strong current from GlobCurrent surface total current from CMEMS and from surface current from Mercator 1/12 assimilated model. W

**Software tools used in this lecture:**

Ocean Virtual Laboratory (OVL) web portal https://ovl.oceandatalab.com

**Data sets used in this lecture:**

Online web portal

**Key papers for background reading:**

1. Video tutorials for Syntool: https://www.youtube.com/playlist?list=PL_Nrq3gZvmM-rrE64qr7QqzQir23kzol1

## 5.33. ESTIMATING SEA STATE FROM SPACE USING SYNTHETIC APERTURE RADAR (SAR)

**Date and time:** 18th February 2025 16:30-17:10

**Lecturer:** Bertrand Chapron (IFREMER)

**Aim of the lecture:** By the end of this lecture, you should understand how satellite synthetic aperture radar (SAR) provides oceanographic information of the sea surface.

**Objectives of the lecture:**

OBJ-1: Explain how synthetic aperture radar images the sea surface

OBJ-2: Introduce synthetic aperture radar satellite instruments

OBJ-3: Show by example what oceanographic information can be derived from SAR sensors viewing the ocean surface

**Abstract:** In this lecture we examine and review basics of ocean surface imaging mechanisms, especially the potential to retrieve directional surface wave information from satellite sensors, as well as main guidance to interpret surface roughness manifestations of ocean features such as meandering fronts with convergence and divergence zones, eddies, and internal waves observed in optical and SAR images. Using different satellite sensors, sea state information can thus be obtained over the global ocean. In particular, a methodology will be presented to routinely derive integral properties of the longer-wavelength (swell) portion of the wave spectrum from all available SAR products, and both monitor and predict their evolution across ocean basins. More locally, major mechanisms responsible for the manifestation of distinct ocean features are: wave-current interactions and suppression of short wind wave by surfactants (accumulated in the current convergence).

To understand and correctly interpret high-resolution images of the ocean surface, it is necessary to jointly-consider the imaging model with a description of background wind waves and their transformation in a non-uniform medium. More precisely, wave-current interactions are well described using the wave action conservation principle. Simplified in its relaxation approximation, such a principle offers means to interpret high-resolution satellite images to further help quantify surface current gradients. In particular, such an approximation is key to understand mechanisms leading to image Internal Solitary Wave

(ISW), as well as to better interpret observations and differences according to different radar wave bands. The fundamental imaging mechanisms in synthetic aperture radar (SAR) images will be described, as well as general wave-current properties. You should be able to understand why internal waves are detected with optical sensors and/or using various radar wave bands, and how a subsurface hydrodynamic phenomenon can acquire a surface manifestation capable of being detected from space. Various sub-mesoscale ocean features shall be discussed as well as typical atmospheric boundary layer effects in high-resolution satellite images.

**Software tools used in this lecture:**

None

**Data sets used in this lecture:**

None

**Key papers for background reading:**

1. Chapron Bertrand, Johnsen H, Garello R (2001). Wave and wind retrieval from SAR images of the ocean . Annales Des Telecommunications Annals Of Telecommunications , 56(11-12), 682-699 .
2. Collard Fabrice, Ardhuin Fabrice, Chapron Bertrand (2009). Monitoring and analysis of ocean swell fields from space: New methods for routine observations . Journal Of Geophysical Research Oceans , 114, - . Publisher's official version : http://doi.org/10.1029/2008JC005215 , Open Access version : http://archimer.ifremer.fr/doc/00000/11101/
3. Kudryavtsev Vladimir, Kozlov I., Chapron Bertrand, Johannessen J. A. (2014). Quad-polarization SAR features of ocean currents . Journal Of Geophysical Research-oceans , 119(9), 6046-6065 . Publisher's official version : http://doi.org/10.1002/2014JC010173 , Open Access version : http://archimer.ifremer.fr/doc/00210/32152/
4. Kudryavtsev, V., D. Akimov, J. Johannessen, and B. Chapron (2005), On radar imaging of current features: 1. Model and comparison with observations, J. Geophys. Res., 110, C07016, doi:10.1029/2004JC002505.
5. Vladimir N. Kudryavtsev, Bertrand Chapron, Alexander G. Myasoedov, Fabrice Collard, and Johnny A. Johannessen (2013), On Dual Co-Polarized SAR Measurements of the Ocean Surface, IEEE Geoscience and Remote Sensing Letters, VOL. 10, NO. 4.

## 5.34. DIRECTIONAL WAVE SPECTRUM FROM SPACE

**Date and time:** 18th February 2025 17:30-18:15

**Lecturer:** Dr Bertrand Chapron (IFREMER) and Dr Fabrice Collard (ODL)

**Aim of the lecture:** At the end of this lecture, you should understand the how to estimate a directional wave spectrum from satellite measurements.

**Objectives of the lecture:**

OBJ-1: Understand different approaches to directional wave spectrum measurements from space

OBJ-2: Interpret the directional wave spectrum measurements from space

**Abstract:** This lecture will explore how different satellite measurements can be used to derive estimates of the directional wave spectrum.

**Software tools used in this lecture:**

1. OVL Portal
2. SeaScope and Python/jupyter notebook for

**Data sets used in this lecture:**

None

**Key papers for background reading:**

## 5.35. DIRECT OBSERVATIONS OF THE OCEAN TOTAL SURFACE CURRENTS FROM SENTINEL-1 SYNTHETIC APERTURE RADAR

**Date and time:** 11th February 2025 17:30-17-50

**Lecturer:** Artem Moiseev (NERSC)

**Aim of the lecture:** At the end of this lecture, you should understand Doppler shift-based radial surface current retrievals from Synthetic Aperture Radars

**Objectives of the lecture:**

OBJ-1: Demonstrate how Sentinel-1 data can be used to retrieve radial surface current retrievals

OBJ-2: Interpret the ocean surface signals measured by Synthetic Aperture Radar systems

**Abstract:**

Accurate and systematic observations of surface currents in coastal regions pose significant challenges for existing ocean observing systems. This lecture will explore how Doppler shift-based radial surface current retrievals from Synthetic Aperture Radars, specifically Sentinel-1, can enhance existing coastal observations with more comprehensive and high-resolution mapping of the coastal ocean surface currents. We will begin by introducing the fundamental principles of Doppler shift observations using Sentinel-1 SAR. Following this, we will discuss the separation of signal attributed to wind, waves, and currents. The lecture will conclude with an analysis of several case studies, comparing these findings with other available observational data.

### Software tools used in this lecture:

1. OVL Portal /Narval/MyOcean (TBD) for generic visualisations
2. SeaScope and Python/jupyter notebook for visualisations and ocean surface current retrieval example

### Data sets used in this lecture:

None

### Key papers for background reading:

1. Krug, M., Mouche, A., Collard, F., Johannessen, J. A., and Chapron, B. (2010), Mapping the Agulhas Current from space: An assessment of ASAR surface current velocities, J. Geophys. Res., 115, C10026, doi:10.1029/2009JC006050.
2. Chapron, B., F. Collard, and F. Ardhuin (2005), Direct measurements of ocean surface velocity from space: Interpretation and validation, J. Geophys. Res., 110, C07008, doi:10.1029/2004JC002809
3. Hansen, M. W., Johannessen, J. A., & Raj, R. P. (2012). Mapping the Nordic Seas surface velocity using Envisat ASAR. Proceedings of the ESA SeaSAR.
4. R. Romeiser, H. Runge, S. Suchandt, R. Kahle, C. Rossi and P. S. Bell, "Quality Assessment of Surface Current Fields From TerraSAR-X and TanDEM-X Along-Track Interferometry and Doppler Centroid Analysis," in IEEE Transactions on Geoscience and Remote Sensing, vol. 52, no. 5, pp. 2759-2772, May 2014, doi: 10.1109/TGRS.2013.2265659.
5. Moiseev, A., Johannessen, J. A., & Johnsen, H. (2022). Towards retrieving reliable ocean surface currents in the coastal zone from the Sentinel-1 Doppler shift observations. Journal of Geophysical Research: Oceans, 127, e2021JC018201., https://doi.org/10.1029/2021JC018201

## 5.36. JUPYTER NOTEBOOK ON SURFACE CURRENT ESTIMATION FROM SENTIONEL-1 DOPPLER SHIFT IN THE MED SEA.

**Date and time:** 18th February 2025 17:50-18:15

**Lecturer:** Dr. Fabrice Collard (ODL)

**Aim of the lecture:** Learn how to use the Doppler shift in Sentinel-1 Level2 OCN products to estimate radial surface current.

**Objectives of the lecture:**

OBJ-1: Understand the Sentinel-1 Level2 OCN products RVL component and how to calibrate it.

OBJ-2: Estimate the sea state Doppler and retrieve the radial surface current

**Abstract:** This practical session will work through examples of sea state Doppler signal and estimation of the ocean surface radial surface current.

**Software tools used in this lecture:**

1. SeaScope and Python/jupyter notebook for visualisations and ocean surface current retrieval example

**Data sets used in this lecture:**

Sentinel-1 Level2 OCN calibrated products

## 5.37. RADAR SCATTEROMETRY OVER THE OCEAN

**Date and time:** 25th February 2025 16:30-16:50

**Lecturer:** Dr Ad Stoffelen (KNMI, The Netherlands)

**Aim of the lecture:** Scatterometers are designed to measure ocean vector winds and in the lecture I'll explain how this is done and how the technique develops.

**Objectives of the lecture:**

OBJ-1: To provide a geophysical understanding of scatterometer vector winds;

OBJ-2: To explain the different measurement geometries of scatterometers and how we can intercalibrate them;

OBJ-3: To provide a basic understanding of wind vector retrieval and wind retrieval accuracy.

**Abstract:**

A radar scatterometer is an instrument used to measure the scattering of radar signals from the Earth's surface. The scatterometer emits microwave radar pulses, which can penetrate clouds and measure the surface in nearly all weather conditions, making it effective for continuous monitoring. When transmitted radar wave pulses hit the ocean surface, they scatter based on the surface roughness characteristics. The scatterometer's antennas collect the backscattered signals, allowing the strength and phase of these backscattered signals to be measured. The received signals are processed to analyse the surface scattering properties, that can be used to infer information about wind speed and direction (wind vector) over oceans.

Satellite scatterometers either use multiple antennas or a rotating antenna system to collect data over a wide area while allowing signals to be received from different azimuth angles. The latter is important to resolve wind direction ambiguities in the returned signal. Scatterometer instruments are designed to provide wide-swath coverage for global wind field monitoring at a matching spatial resolution.

**Software tools used in this lecture:**

- Scatterometer wind retrieval software is available in the EUMETSAT NWP SAF.

**Data sets shown in this lecture:**

- Swath vector winds are displayed at https://scatterometer.knmi.nl and available in the EUMETSAT OSI SAF.

**Key papers for background reading:**


1. Ad Stoffelen in Google Scholar;
2. Hauser, D., Abdalla, S., Ardhuin, F. et al. Satellite Remote Sensing of Surface Winds, Waves, and Currents: Where are we Now?. Surv Geophys 44, 1357–1446 (2023). https://doi.org/10.1007/s10712-023-09771-2;
3. Kloe, J. de, A. Stoffelen and A. Verhoef, 2017, Improved Use of Scatterometer Measurements by Using Stress-Equivalent Reference Winds, IEEE JSTARS 10 (5), 2340-2347, https://doi.org/10.1109/JSTARS.2017.2685242;
4. Vogelzang, Jur, and Ad Stoffelen. 2024. "A Land-Corrected ASCAT Coastal Wind Product" Remote Sensing 16, no. 12: 2053. https://doi.org/10.3390/rs16122053;
5. Vogelzang, Jur, and Ad Stoffelen. 2022. "On the Accuracy and Consistency of Quintuple Collocation Analysis of In Situ, Scatterometer, and NWP Winds" Remote Sensing 14, no. 18: 4552. https://doi.org/10.3390/rs14184552.


## 5.38. VECTOR WINDS DERIVED FROM RADAR SCATTEROMETRY OVER THE OCEAN

**Date and time:** 25th February 2025 16:50 – 17:10

**Lecturer:** Dr Ad Stoffelen (KNMI, The Netherlands)

**Aim of the lecture:** At the end of this lecture you should understand the satellite radar scatterometry measurements of wind speed over the ocean.

**Objectives of the lecture:**

OBJ-1: To describe the ocean vector winds processing and characteristics of hourly gridded products;

OBJ-2: To explain how observed vector winds change over time; compare to in-situ and model vector winds;

OBJ-3: Elaborate how tropical hurricane winds change over time?

**Abstract:**


Ocean vector winds at the ocean surface are available for several decades now and are important to understand the coupling between the atmosphere and the ocean. Scatterometer ocean vector winds are available since 1992 and processed into hourly gridded products of vector winds and stresses. The lecture briefly explains how this is done and furthermore comparisons between model winds and observed scatterometer vector winds will be elaborated in view of describing large and persistent model wind forcing errors.

Surface vector winds force the oceans and are associated with all dynamical features and modes in the atmosphere and the ocean, such as tropical moisture convergence and hurricanes. This lecture will use examples to highlight "what climate wind changes do we observe?"

**Software tools used in this lecture: None**

None

**Data sets shown in this lecture:**

- Copernicus Marine Service Wind TAC

**Key papers for background reading:**

1. Ad Stoffelen in Google Scholar;
2. Belmonte Rivas, Belmonte Rivas, M. and Stoffelen, A. , 2019, Characterizing ERA-Interim and ERA5 surface wind biases using ASCAT, Ocean Sci., 15, 831–852, https://doi.org/10.5194/os-15-831-2019;
3. Verhoef, A., Vogelzang, J., Verspeek, J., and Stoffelen, A., 2017, Long-Term Scatterometer Wind Climate Data Records, IEEE JSTARS 10 (5), https://doi.org/10.1109/JSTARS.2016.2615873;
4. Ni, Weicheng, Ad Stoffelen, Kaijun Ren, Xiaofeng Yang, and Jur Vogelzang, 2022, SAR and ASCAT Tropical Cyclone Wind Speed Reconciliation, Remote Sensing 14 (21), 5535. https://doi.org/10.3390/rs14215535

## 5.39. OCEAN SIGNATURES FROM OPTICAL SUN GLITTER

**Date and time:** 25th February 2025 17:30-17:50

**Lecturer:** Dr Bertrand Chapron (IFREMER) and Dr Fabrice Collard (ODL)

**Aim of the lecture:** At the end of this lecture you will have an understanding of how optical sun-glitter measurements from satellite instruments can be used to study the ocean surface.

**Objectives of the lecture:**

OBJ-1: To understand the measurement principles of ocean sun-glitter from space

OBJ-2: Understand the strengths and limitations of satellite sun-glitter measurements over the ocean

**Abstract:** Sunglint measurements made from satellite instruments at multiple angles offer the only means of observing simultaneously waves, surface current and wind at very high spatial resolution. Such observations can be used to unravel spatial heterogeneities of air-sea interactions and understand how the ocean "breathes", i.e. how air-sea fluxes are distributed from the global scale down to the scale of atmospheric convective cells and

oceanic eddies and fronts. Multi-azimuth observations at short time lag and high resolution help coastal geomorphology investigations, to help precisely trace impacts of coastal storms. Sunglint measurements of the ocean surface from space are also useful to provide reference measurements of waves, currents and wind, especially to validate and calibrate other indirect estimates from operational instruments like altimeters or radars. With a quasi-global coverage, high resolution observations provide very precise needed information in terms of directional waves, surface current vector including its vertical shear, and wind vector.

### Software tools used in this lecture:

1. https://www.oceandatalab.com/syntool
2. https://seascope.oceandatalab.com/

**Data sets used in this lecture:** many data sets are included in the tools. Refer to the respective web pages for more information

### Key papers for background reading:


1. Bréon, F. M., and N. Henriot, Spaceborne observations of ocean glint reflectance and modeling of wave slope distributions, J. Geophys. Res. 111, C06005, doi:10.1029/2005JC003343, 2006.
2. Chust, G. and Y. Sagarminaga, The multi-angle view of MISR detects oil slicks under sun glitter conditions, Remote Sens. Environ., 107, 1-2, 232-239, doi:10.1016/j.rse.2006.09.024, 2007.
3. Cox, C. and W. Munk, "Measurement of the roughness of the sea surface from photographs of the Sun's glitter," J. Opt. Soc. Am. 44, 838–850, 1954a.
4. Cox, C. and W. Munk, "Statistics of the sea surface derived from Sun glitter," J. Mar. Res. 13, 198–227, 1954b.
5. Rascle, N., B. Chapron, A. Ponte, F. Ardhuin, and P. Klein, Surface Roughness of currents shows divergence and strain in the wind direction, J. Phys. Oceanogrgraphy, DOI: 10.1175/JPO-D-13-0278.1, 2014
6. Kay, S., J. Hedley, S. Lavender, and A. Nimmo-Smith, "Light transfer at the ocean surface modeled using high resolution sea surface realizations," Opt. Express 19, 6493–6504, 2011.

7. Adamo, M., G. De Carolis, V. De Pasquale, and G. Pasquariello, Combined use of SAR and MODIS imagery to detect marine oil spills, SAR Image Analysis, Modeling, and Techniques VII. Edited by Posa, Francesco, Proceedings of the SPIE, Volume 5980, pp. 153-164, 2005.
8. Doerffer, R., H. Schiller, J. Fischer, R. Preusker, and M. Bouvet, "The impact of Sun glint on the retrieval of water parameters and possibilities for the correction of MERIS scenes," presented at 2nd MERIS/(A)ATSR User Workshop, ESA/ESRIN Frascati, Rome, Italy, 22–26 Sept. 2008.
9. Ebuchi, N. and S. Kizu, "Probability distribution of surface wave slope derived using Sun glitter images from geostation- ary meteorological satellite and surface vector winds from scatterometers," J. Oceanogr. 58, 477–486, 2002.
10. Hennings, I., J. Matthews, and M. Metzner (1994), Sun glitter radiance and radar cross-section modulations of the sea bed, J. Geophys. Res., 99(C8), 16,303–16,326.

11. Hu, C., X. Li, W. G. Pichel, and F. E. Muller-Karger, Detection of natural oil slicks in the NW Gulf of Mexico using MODIS imagery, Geophys. Res. Lett., 36, L01604, doi:10.1029/2008GL036119, 2009.
12. Jackson C.R., and W. Alpers (2010), The role of the critical angle in brightness reversals on sunglint images of the sea surface, J.Geoph. Res. VOL. 115, C09019, doi:10.1029/2009JC006037
13. Johannessen J., B. Chapron, F. Collard, V. Kudryavtsev, A. Mouche, D. Akimov, and K.- F. Dagestad, Direct ocean surface velocity measurements from space: Improved quantitative interpretation of Envisat ASAR observations, Geoph. Res. Letter, 35, L22608, 2008
14. Johannessen, J., Kudryavtsev, V., Akimov, D., Eldevik, T., Winther, N., Chapron, B., On radar imaging of current features: 2. Mesoscale eddy and current front detection. Journal of Geophysical Research 110, C07017, 2005.
15. Kay, S., J. Hedley and S. Lavender, Sun glint estimation in marine satellite images: a comparison of results from calculation and radiative transfer modeling, App. Optics, 52, 5631- 5639, 2013.
16. Kudryavtsev,V.,Myasoedov,A.,Chapron,B.,Johannessen,J.A.,Collard,F. Joint sun-glitter and radar imagery of surface slicks. Remote Sensing of Environment 120, 123–132, 2012.
17. Kudryavtsev V., Alexander Myasoedov, Bertrand Chapron, Johnny A. Johannessen, Fabrice Collard, Joint sun-glitter and radar imagery of surface slicks, Remote Sensing of Environment, ISSN 0034-4257, doi: 10.1016/j.rse.2011.06.029, 2012b.
18. Kudryavtsev V., D.Akimov, J.A.Johannessen, and B. Chapron, On radar imaging of current features. Part 1: Model and comparison with observations, Journal of Geophysical Research, Vol. 110, C07017, 2005.
19. Kudryavtsev, V., D. Hauser, G. Caudal, and B. Chapron, A semi-empirical model of the normalized radar cross-section of the sea surface. Part 1: Background model, Journal of Geophysical Research, 108(C3), 8054, doi:10.1029/2001JC001003, 2003.
20. Kudryavtsev, V., Myasoedov, A., Chapron, B., Johannessen, J. A., Collard, F., Imaging mesoscale upper ocean dynamics using synthetic aperture radar and optical data. Journal of Geophysical Research: Oceans (1978–2012) 117, 2012a.
21. Myasoedov A., V. Kudryavtsev, B. Chapron, J. Johannessen. Sun glitter imagery of the ocean phenomena. Proceedings of the “SeaSAR 2010”, Frascati, Italy, 25-29 January 2010 (ESA SP-679, April 2010)


## 5.40. OCEAN SURFACE ROUHGHNESS SATELLITE MEASURMENTS IN SYNERGY

**Date and time:** 25th February 2025 17:50-18:15

**Lecturer:** Dr Bertrand Chapron (IFREMER) and Dr Fabrice Collard (ODL)

**Aim of the lecture:** At the end of this lecture, you should understand how surface ocean roughness signatures derived from different satellite techniques can be used to yield more information in synergy

**Objectives of the lecture:**

OBJ-1: How to apply different ocean surface roughness measurements in synergy

**Abstract:** Ocean current systems are characterised by a complex sea state regime. This interactive lecture will show examples of waves and highlight their characteristics and mechanisms for their formation and propagation using different satellite data in synergy

**Software tools used in this lecture:**

1. https://www.oceandatalab.com/syntool
2. https://seascope.oceandatalab.com/

**Data sets used in this lecture:** many data sets are included in the tools. Refer to the respective web pages for more information

**Key papers for background reading:**

None

## 5.41. PRESENTATION FROM EACH STUDENT OR STUDENT GROUP ON RESEARCH PLANS

**Date and time:** 11th March 2025 16:30-18:15

**Lecturer:** None

**Aim of the Session:** At the end of this session, you should understand the research plans being prepared by students for the OTC25 course.

**Objectives of the lecture:**

OBJ-1: Understand what each Student/Student group will be working on aboard the ship

OBJ-2: Develop collaborations between Students before arriving at the ship to achieve better outcomes for scientific activities

**Abstract:** Each Student or Student group will present their research plans in plenary using a maximum of 5 slides. The group. Can then ask questions and try to establish commonalities and areas of collaboration to achieve scientific aims and objectives. The session should be light hearted and in the spirit of good collaboration.

## 5.42. PHYSICAL MECHANISMS FOR AIR-SEA GAS EXCHANGE

**Date and time:** 11th March 2025 16:30-17:10

**Lecturer:** Prof. Anna Rutgersson (Uppsala University)

**Aim of the lecture:** At the end of this lecture, you should understand the basic mechanisms of ocean-atmosphere gas exchange.

**Objectives of the lecture:**

OBJ-1: Understand how acoustic measurements for ocean science are made

OBJ-2: Interpret the ocean acoustic signals from shipboard measurements

**Abstract:**

The air-sea exchange of carbon dioxide (and other gases) is generally controlled by the air-sea gradient (or difference in partial pressure) and by the efficiency of the exchange. The lecture will focus on the mechanisms controlling the gas exchange. Gases of low solubility are generally water-side controlled (like carbon dioxide), and gases of high solubility are air-side controlled (water vapor), this can be described by resistances to the exchange. Resistances are depending on a range of processes including, surfactants, surface waves, bubbles and sea spray and temperature stratification. The lecture will cover the different mechanisms and the importance of different types of gases, it will also include methods to calculate the air-sea fluxes and briefly methods to measure it.

Using observations of surface pCO2 and wind speed to calculate air-sea gas exchange. In addition, use EO proxies to estimate surface pCO2 and compare calculated air-sea fluxes. pCO2 data are initially from the Östergarnsholm-site in the Baltic Sea and later on data taken at the different legs of the cruise, suggested EO data are winds/waves, ocean colour, SST and SSS

**Software tools used in this lecture:**

None

**Data sets used in this lecture:**

None

**Key papers for background reading:**

1. Garbe et al
2. Rutgersson et al

## 5.43. CALCULATING GLOBAL ATMOSPHERE-OCEAN CO2 GAS FLUXES USING SATELLITE, IN SITU AND MODELLING DATA (IN SYNERGY)

**Date and time:** 11th March 2025 17:30 – 18:15

**Lecturer:** Dr Jamie Shutler (University of Exeter)

**Aim of the lecture:** This lecture will go through two of the interaction iPython tutorials that come packaged with the FluxEngine toolbox to demonstrate how to calculate atmosphere-ocean CO2 gas fluxes.

**Objectives of the lecture**

OBJ-1: Demonstrate how to begin using the fluxEngine toolbox for calculating global atmosphere-ocean CO2 gas fluxes using satellite, model and in situ data in synergy.

OBJ-2 Demonstrate global atmosphere-ocean CO2 gas flux results and how to calculate the net integrated oceanic sink.

**Abstract:** This lecture will go through some of the interactive iPython tutorials that come packaged with the FluxEngine toolbox and so we will demonstrate how to calculate atmosphere-ocean CO2 gas fluxes using the toolbox. The toolbox itself is introduced in Shutler et al (2016) and then the first two case studies described in Section 3 of Holding et al, (2019) are the two tutorials that we will focus on. The first tutorial demonstrates global atmosphere-ocean CO2 gas fluxes and verifies that the toolbox has been correctly installed. The second tutorial illustrates how you can calculate the gas fluxes along a research cruise track using a combination of in situ cruise data and satellite data. So reading these papers in advance of the interaction lecture will allow you to easily follow the content of the lecture.

**Software tools used in this lecture:**

1. Python 3.6 (or newer), The Python FluxEngine toolbox (e.g. available using 'pip install fluxengine') and all of its dependencies.

**Data sets used in this lecture:**

All data are packaged with the FluxEngine toolbox.

**Key papers for background reading:**

1. Shutler JD, et al., (2016). FluxEngine: a Flexible Processing System for Calculating Atmosphere–Ocean Carbon Dioxide Gas Fluxes and Climatologies. Journal of Atmospheric and Oceanic Technology, 33(4), 741-756
2. Shutler JD, et al., (2020). Satellites will address critical science priorities for quantifying ocean carbon. Frontiers in Ecology and the Environment, 18(1), 27-3
3. Holding T, et al., (2019). The FluxEngine air-sea gas flux toolbox: simplified interface and extensions for in situ analyses and multiple sparingly soluble gases. Ocean Science, 15(6), 1707-1728

## 5.44. EXPLORING THE BIOLOGICAL CARBON CYCLE: WHERE BIOLOGY MEETS CHEMISTRY TO CONNECT ATMOSPHERE TO SEAFLOOR

**Date and time:** 18th March 2025 16:30-17:10

**Lecturer:** Dr. Saskia Rühl

**Aim of the lecture:** By the end of this lecture, you should understand practical sensing and sampling solutions to track particulate carbon throughout the water column in situ.

### Objectives of the lecture

OBJ-1: Understand practical sensing and sampling solutions to track particulate carbon throughout the water column in situ.

OBJ-2: Introduce sensors and samplers that will be available for use during the One Ocean 2025 expedition.


### Abstract

Phytoplankton take up vast amounts of carbon dioxide from the atmosphere each day through photosynthesis. Once incorporated, the carbon can travel along various pathways, fuelling grazers and predators along the way, and either be recycled or exported through biological, chemical or physical means. Remote sensing can give us information on near-surface biological activity over broad spatial scales, and using in-situ sampling, sensors and imaging solutions provides an opportunity to trace vertical transport.

Here, we explore practical sensing and sampling solutions to track particulate carbon throughout the water column in situ, with a particular focus on sensors and samplers that will be available for use during the One Ocean 2025 expedition.


### Software tools used in this lecture:

None

### Data sets used in this lecture:

None

### Key papers for background reading:


1. Sanders et al. 2014, The Biological Carbon Pump in the North Atlantic, https://www.sciencedirect.com/science/article/abs/pii/S0079661114000901?via%3Dihub
2. Steinberg & Landry, 2017, Zooplankton and the Ocean Carbon Cycle, Zooplankton and the Ocean Carbon Cycle | Annual Reviews
3. Siegel et al. 2023, Quantifying the Ocean's Biological Pump and Its Carbon Cycle Impacts on Global Scales | Annual Reviews


## 5.45. THE AMAZING CARBON CYCLE AND THE COMPLETE OCEAN CARBON CYCLE: THE OCEAN CARBON SINK, ACIDIFICATION AND CONSERVATION

**Date and time:** 18th March 2025 17:30-18:15

**Lecturer:** Jamie Shutler (University of Exeter)

**Aim of the lecture:** By the end of this lecture, you should understand the global carbon cycle and its importance for all life on Earth, ocean-atmosphere interactions, how carbon enters and moves in the ocean, where it goes and the relevance of the marine inorganic carbonate cycle.

### Objectives of the lecture:

OBJ-1: Why are synergy approaches are key for quantifying important exchanges of carbon

OBJ-2: How satellite and in-situ observational-based approaches are increasingly important for quantifying the flow and pools of carbon for guiding international and government policies

### Abstract:

Here we will introduce the global carbon cycle and its importance for all life on Earth, including humans through to the food we eat and the animals that live in the oceans. We will then cover ocean-atmosphere interactions, how carbon enters and moves in the ocean, where it goes and the relevance of the marine inorganic carbonate cycle. We will then discuss how synergy approaches are key for quantifying these important exchanges of carbon, and how these satellite, and in-situ observational-based approaches are increasingly important for quantifying the flow and pools of carbon for guiding international and government policies. Finally, we will discuss how these satellite and in-situ methods are now beginning to be used for directly guiding ocean management and conservation decisions, that are now needed due to the long-term acidification of the oceans caused by the unabating carbon emissions from humans.

### Activities on the Ship

Access to the underway pCO2 and ideally three associated SSTs (the SST from the same depth/inlet as the water that feeds the pCO2 instrument, the SST of the water in the equilibrator, and the IR SST skin data – so three different SST datasets).

### Software tools used in this lecture:

Python (iPython Jupyter notebooks) run via a remote server. During the practical we will use to iPython Jupyter notebooks to determine the complete inorganic carbonate system from some example in-situ data. These methods will allow you to analyse the in-situ data you collect whilst onboard the Statraad Lehmkhul to study the marine carbonate system, including the water alkalinity, pH, and the atmosphere-ocean exchange of CO2.

### Data sets used in this lecture:

TBD

### Key papers for background reading:

1. Archer, D., 2011. The global carbon cycle. Prinon University Press (available online for free).
2. Brewin, R.J., Sathyendranath, S., Platt, T., Bouman, H., Ciavatta, S., Dall'Olmo, G., Dingle, J., Groom, S., Jönsson, B., Kostadinov, T.S. and Kulk, G., 2021. Sensing the ocean biological

carbon pump from space: A review of capabilities, concepts, research gaps and future developments. Earth-Science Reviews, 217, p.103604.
3. Brewin, R.J., Sathyendranath, S., Kulk, G., Rio, M.H., Concha, J.A., Bell, T.G., Bracher, A., Fichot, C., Frölicher, T.L., Galí, M. and Hansell, D.A., 2023. Ocean carbon from space: Current status and priorities for the next decade. Earth-science reviews, 240, p.104386.
4. Land, P.E., Shutler, J.D., Findlay, H.S., Girard-Ardhuin, F., Sabia, R., Reul, N., Piolle, J.F., Chapron, B., Quilfen, Y., Salisbury, J. and Vandemark, D., 2015. Salinity from space unlocks satellite-based assessment of ocean acidification.
5. Shutler, J.D., Wanninkhof, R., Nightingale, P.D., Woolf, D.K., Bakker, D.C., Watson, A., Ashton, I., Holding, T., Chapron, B., Quilfen, Y. and Fairall, C., 2020. Satellites will address critical science priorities for quantifying ocean carbon. Frontiers in Ecology and the Environment, 18(1), pp.27-35.
6. Shutler, J.D., Gruber, N., Findlay, H.S., Land, P.E., Gregor, L., Holding, T., Sims, R.P., Green, H., Piolle, J.F., Chapron, B. and Sathyendranath, S., 2024. The increasing importance of satellite observations to assess the ocean carbon sink and ocean acidification. Earth-Science Reviews, 250, p.104682.

## 5.46. TRACKING SEA ICE FROM SPACE

**Date and time:** 25th March 2025 16:30-16:50

**Lecturer:** Prof. Andrew Shepard (University of Northumbria, United Kingdom)

**Aim of the lecture:** At the end of this lecture, you will understand the importance of measurement sea ice from space and the basic techniques used for this purpose

**Objectives of the lecture:**

OBJ-1: Understand how we track changes in Earth's sea ice extent, thickness, and volume from space,

OBJ-2: Understand how sea ice reacts and interacts with the global climate system.

**Abstract:**

Fluctuations in Earth's ice cover have been driven by changes in the planetary radiative forcing, affecting global sea level, oceanic conditions, atmospheric circulation and freshwater resources. The polar ice sheets store more than 99 % (30 million km3) of Earth's freshwater ice on land, and even modest losses raise the global sea level, increase coastal flooding and disturb oceanic currents.  Typically, 15 to 25 million km2 of the global ocean surface is covered in sea ice at any one time of year, though its thickness and extent vary seasonally and due to long-term changes in Earth's climate. Sea ice plays a key role in the freshwater and energy budgets of the polar regions, impacts the marine ecosystem, and regulates the absorption of solar radiation in summer (Pistone et al., 2014). Furthermore, sea ice loss could influence oceanic and atmospheric circulation and affect weather patterns in the mid-latitudes. Although Arctic sea ice has progressively declined, sea ice

in the Southern Ocean has expanded during most of the first four decades of satellite observations. However, in 2016 the Antarctic sea ice area plummeted, in a change far outside the range of previously observed variability. Neither the increasing trend nor the rapid decline are authentically simulated by climate models, casting doubt on their ability to represent associated processes including Southern Ocean heat and carbon uptake, melting of the Antarctic Ice Sheet, and many other aspects of the Southern Hemisphere climate.

In this lecture I will explain how we track changes in Earth's sea ice extent, thickness, and volume from space, and how it reacts and interacts with the global climate system. I will discuss the DEFIANT project, which is investigating the drivers and effects of fluctuations in sea ice in the Southern Ocean. The project will generate a new mechanistic understanding of the drivers and impacts of Antarctic sea ice variability, including the dramatic decline in 2016. To achieve this overarching goal, we have launched an ambitious, internationally leveraged field programme to provide the first comprehensive, systematic, year-round measurements of atmospheric and oceanic conditions at the Antarctic air sea-ice interface. The project involves the collection of new measurements from subsurface gliders, autonomous submersibles, remote ice mass balance buoys, in situ stations, ice strengthened ships, fixed-wing aircraft, helicopter, and satellite platforms. We will use these observations to create and validate new physical models of sea ice snow loading and satellite retrievals of sea ice thickness, making use of CryoVex, CryoSat-2 and ICESat-2 radar and laser altimetry. These retrievals and measurements will in turn be used to constrain a hierarchy of numerical models and apply them to understand the processes controlling the historical decadal sea ice expansion and 2016 decline. Finally, we will assess the short-term and decadal consequences of Antarctic sea ice variability. Through this interlinked programme of observations, model development and model evaluation, DEFIANT will deliver a step-change in our understanding of the Antarctic sea ice system.

### Software tools used in this lecture:

None.

### Data sets used in this lecture:

None.

### Key papers for background reading:


1. W. Abdalati et al., "The ICESat-2 Laser Altimetry Mission," in Proceedings of the IEEE, vol. 98, no. 5, pp. 735-751, May 2010, doi: 10.1109/JPROC.2009.2034765.
2. D.J. Wingham, C.R. Francis, S. Baker, C. Bouzinac, D. Brockley, R. Cullen, P. de Chateau-Thierry, S.W. Laxon, U. Mallow, C. Mavrocordatos, L. Phalippou, G. Ratier, L. Rey, F. Rostan, P. Viau, D.W. Wallis, 2006, CryoSat: A mission to determine the fluctuations in Earth's land and marine ice fields, Advances in Space Research,37, 841-871, https://doi.org/10.1016/j.asr.2005.07.027.
3. DEFIANT Project: https://cpom.org.uk/esa-cryovex-defiant-antarctica-campaign/Cryosat-2

## 5.47. SAFE NAVIGATION IN SEA ICE INFESTED WATERS

**Date and time:** 25th March 2025 16:50-17:10

**Lecturer:** Anton Korosov (NERSC, Bergen, Norway)

**Aim of the lecture:** We will use near real time satellite data from PMW, SAR and optical sensors to locate sea ice edge, analyse the state of sea ice cover and ice dynamics, and to make tactical prognosis of the situation for estimate risks of navigation in open waters or inside the ice pack.

**Objectives of the lecture:**

OBJ-1: How to detect sea ice on satellite data and assess its properties

OBJ-2: How to plan safe navigation in ice infested waters

**Abstract:**

Sea ice plays a vital role in Earth's climate system by reflecting sunlight and regulating global temperatures. It also serves as a critical indicator of environmental change, making its monitoring essential. Satellite technology offers global coverage of remote polar regions, long-term data collection, and detailed measurements of ice extent, thickness, and movement. This information helps scientists track trends, refine climate models, and understand the broader impact of sea ice on global systems.

Additionally, satellite monitoring supports safe navigation through polar waters as melting ice opens new shipping routes. Overall, satellites provide the comprehensive and precise data needed to assess the health of our planet and predict future climate changes, making them indispensable tools in the study of sea ice and its broader implications.

Satellite remote sensing of sea ice employs various technologies, each with unique capabilities to observe and measure different aspects of the ice. Passive microwave sensors are especially valuable for monitoring sea ice because they can penetrate clouds and operate day and night, providing continuous data. These sensors measure the natural microwave emissions from the Earth's surface, allowing scientists to estimate sea ice extent and concentration even in the harshest weather conditions. Passive microwave data has been instrumental in building long-term records of sea ice, making it a cornerstone of climate studies.

Optical sensors and Synthetic Aperture Radar (SAR) complement passive microwave by offering higher-resolution imagery and additional insights. Optical sensors capture visible and infrared light, producing detailed images of the ice surface, which are useful for tracking changes in ice cover and detecting features like melt ponds. However, optical sensors require daylight and clear skies, limiting their use in polar regions. SAR, on the other hand, uses radar pulses to create detailed images of the ice surface, regardless of

weather or lighting conditions. SAR is particularly effective for measuring ice thickness, monitoring ice movement, and detecting small-scale features, making it a powerful tool for comprehensive sea ice analysis. Together, these remote sensing techniques provide a multi-feed view of sea ice, crucial for understanding its behaviour and predicting future changes.

The lecture will cover the basic physics for understanding of passive microwave and SAR remote sensing of sea ice and detail production and usage of the following sea ice products: concentration and extent, thickness, drift.

### Activities on the Ship

Analysis of NRT satellite-derived sea ice products, or historical satellite and model data, ice charts. Simulation of navigation in sea ice. If deployment on sea ice is possible, release of a sea ice drifting buoy.

### Software tools used in this lecture:

We will use OVL Portal and SeaScope with Python Notebooks.

### Data sets used in this lecture:

NRT or historical Sentinel-1 and AMSR2 products together with ice charts from DMI will be used.

### Key papers for background reading:

1. N. Ivanova, O. M. Johannessen, L. T. Pedersen and R. T. Tonboe, "Retrieval of Arctic Sea Ice Parameters by Satellite Passive Microwave Sensors: A Comparison of Eleven Sea Ice Concentration Algorithms," in IEEE Transactions on Geoscience and Remote Sensing, vol. 52, no. 11, pp. 7233-7246, Nov. 2014, doi: 10.1109/TGRS.2014.2310136.
2. Ricker, R., Hendricks, S., Kaleschke, L., Tian-Kunze, X., King, J., and Haas, C.: A weekly Arctic sea-ice thickness data record from merged CryoSat-2 and SMOS satellite data, The Cryosphere, 11, 1607–1623, https://doi.org/10.5194/tc-11-1607-2017, 2017.
3. Korosov, A.A.; Rampal, P. A Combination of Feature Tracking and Pattern Matching with Optimal Parametrization for Sea Ice Drift Retrieval from SAR Data. Remote Sens. 2017, 9, 258. https://doi.org/10.3390/rs9030258

## 5.48. ESA SATELLITE OCEANOGRAPHY: FROM EXPLORATION TO OPERATIONAL OCEANOGRAPHY AND CLIMATE MONITORING

**Date and time:** 1st April 2025 16:30-17:10

**Lecturer:** Dr. Mark Drinkwater (ESA/ESTEC)

**Aim of the lecture:**

**Objectives of the lecture:** to illustrate the evolution of European satellite oceanography since the 1990s, and the development of today's key role which satellite data plays in operational ocean forecasting and climate change monitoring

OBJ-1: Overview of history and evolution of ESA satellite oceanography

OBJ-2: To understand the foresight and long-term planning required to secure continuity in critical satellite oceanographic measurements for operational and climate applications

### Abstract:

With the dawn of satellite remote sensing in the 1970s, traditional oceanographers were provided a new tool to collect synoptic observations of conditions at or near the surface of the global ocean. The launch of SeaSat in 1987 gave a first brief glimpse of the potential of a purpose-built all-weather oceanographic satellite to revolutionise oceanography.

The European Space Agency's journey in satellite oceanography began with the launch of ERS-1 in 1991. Over the last 3 decades, European satellite oceanographic capabilities have evolved dramatically from research missions to investigate different aspects of the ocean (e.g. ERS-1/2, GOCE, SMOS, CryoSat, Swarm) to meteorological missions (e.g. MetOp) and operational oceanography missions (e.g. GMES - now Copernicus Sentinels).

As measurements from space became more robust, together with the security provided by contiguous series of overlapping satellite data records, operational oceanography began to flourish. Today, satellite and in-situ oceanographic data products (e.g. Argo) are routinely integrated and assimilated in state-of-the-art models. The models (e.g. CMEMS) are capable of accurate estimates of the three dimensional, time-varying distribution of properties in the global ocean. Provided the observations can be collected globally on a sustained basis and delivered in a timely way, operational oceanography provides a capability that is conceptually similar to numerical weather forecast models.

Decades of planning have gone into preparing and developing the space-component of Copernicus. Our ability to understand and forecast oceanic and climate variability critically depends on our ability to sustain such an integrated satellite and in-situ ocean observing system in the future.

### On board the ship:

The goal will be to use the integrated satellite and model products during the voyage.

### Key papers for background reading:

1. Figa-Saldaña, J., Wilson, J. J. W., Attema, E., Gelsthorpe, R., Drinkwater, M. R., and Stoffelen, A. The advanced scatterometer (ASCAT) on the meteorological operational (MetOp)

platform: A follow on for European wind scatterometers. Canadian Journal of Remote Sensing, 28(3), 404–412. https://doi.org/10.5589/m02-035, 2002.
2. Drinkwater MR, Francis R, Ratier G, Wingham DJ. The European Space Agency's Earth Explorer Mission CryoSat: measuring variability in the cryosphere. *Annals of Glaciology*, 39, 313-320. doi:10.3189/172756404781814663, 2004.
3. Drinkwater, M., H. Rebhan, P.Y. Le Traon, L. Phalippou, D. Cotton, J. Johannessen, G. Ruffini, P. Bahurel, M. Bell, B. Chapron, I. Robinson, L. Santoleri and D. Stammer. The roadmap for a GMES operational oceanography mission, ESA Bulletin, (124), 42-48, 2005.
4. Kerr, Y.H., P. Waldteufel, J-P. Wigneron, F. Cabot, J. Boutin, M-J. Escorihuela, N. Reul, C. Gruhier, S. Juglea, J. Font, S. Delwart, M.R. Drinkwater, A. Hahne, M. Martin-Neira, and S. Mecklenburg. The SMOS mission: a new tool for monitoring key elements of the global water cycle, *Proc. IEEE*, Vol. 98(5), doi: 10.1109/JPROC.2010.2043032, pp. 666 – 687, 2010.
5. Drinkwater, M.R., R. Haagmans, M. Kern, D. Muzi and R. Floberghagen, Obtaining a portrait of the Earth's most intimate features, ESA Bulletin, 133, 4-13, 2008.
6. Drinkwater, M.R., H. Bonekamp, P. Bontempi, B. Chapron, C. Donlon, J-L. Fellous, P. DiGiacomo, E. Harrison, P.Y. LeTraon, & S. Wilson, Status and Outlook for the Space Component of an Integrated Ocean Observing System. In Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 1), Venice, Italy, 21-25 September 2009, Hall, J., Harrison, D.E. & Stammer, D., Eds., ESA Publication WPP-306, doi:10.5270/OceanObs09. pp.17, 2010.

## 5.49. OBSERVING EXTREME STORM EVENTS FROM SPACE

**Date and time:** 1st April 2025 17:30-18:15

**Lecturer:** Estel Cardellach (Institute of Space Sciences ICE-CSIC, IEEC)

Fabrice Collard (OceanDataLab) Practical

**Aim of the lecture:** By the end of this lecture, you should understand the role of mesoscale variability for the northward transport of the Atlantic Water into the Norwegian Sea.

**Objectives of the lecture:**

OBJ-1: to review of the techniques suitable for observing extreme storm events from Space, most of them already described in previous sessions of the Course.

OBJ-2: to explore new spaceborne techniques under development with potential to complement the observations of extreme events.

**Abstract:**

Events characterised by strong winds blowing over the surface of the sea, large and long waves, and storm surge (high water levels) are identified as extreme storms. At open seas, these storms affect navigation and offshore activities while in coastal areas they become hazardous, causing over-wash and inundation, shore erosion, and damages to coastal

infrastructure. These events can result in lives lost and human injuries in addition to the damages to property and to the environment.

Proper understanding, modelling and forecasting of these events is crucial to mitigate the associated damages, prepare population, alter shipping routes or re-plan offshore activities. It is also important for better assessing the impact of climate change on these types of events, such as potential changes in their frequency, geographic location and intensity. This is only possible with comprehensive measurements of a wide range of variables across these storms (before, during and after the event). The role of the observations is multi-fold: from near-real time information for nowcasting and warning, to deep characterization for scientific studies about their genesis and amplification mechanisms.

Unfortunately, in-situ observation are dangerous to take, thus sparse, while remote measurements are hindered by the opacity of the thick clouds, heavy precipitation and complex roughness (breaks, foam, rain splash) associated to such events. This lecture will give an overview of spaceborne approaches that are suitable to observe under these extreme conditions, from well-established techniques to the novel ones currently under development.

### On board the ship

While the goal of OTC'25 is to help the participants understand and exploit data from satellite missions for ocean science and application development, this activity will attempt to introduce them to the steps required to develop a new remote sensing concept. A completely immature measurement concept will be investigated: would it be possible to estimate ocean variables with the communication signals transmitted at P-band (e.g., UFO COMSAT constellation working at ~250MHz, ~1.2 m wavelength), forward scattered off the rough ocean and collected by an opportunistic receiver? Are these signals more or less sensitive to the sea water permittivity (salt content) than other frequency bands? Could the long electromagnatic wavelength facilitate coherent scattering enabling the tracking of the electomangetic carrier phase, thus precise altimetry, even under rougher surface conditions? Could this be implemented from spaceborne receivers? Simple assumptions and equations will be used to predict potential sensitivity to different ocean surface parameters (e.g., Fresnel reflection coefficient; Rayleigh coherence criterion -- see Figure below; bistatic radar equation); raw signals will be collected with a prototype data grabber, and then processed to test the predicted skills; discussions about expected systematic effects and anticipated challenges; discussions about potential applications.

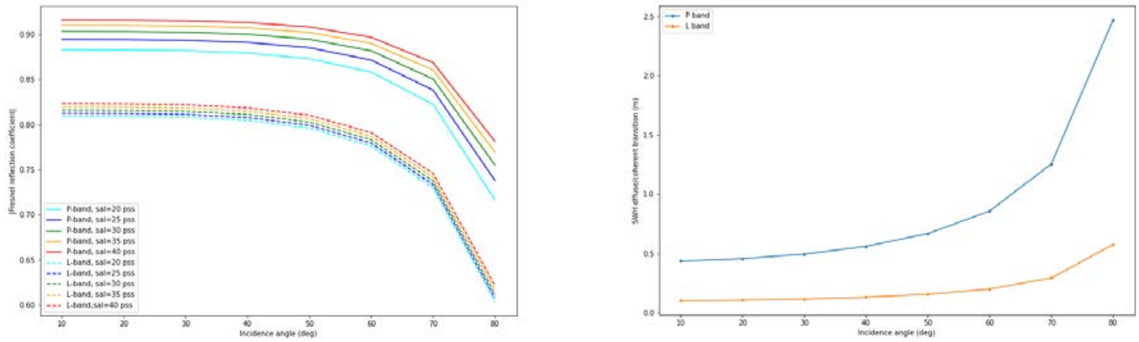


*Figure 1: Left: Fresnel reflection coefficient of cross-polar circular polarization for sea water with different salinity content. Solid/dashed lines for P/L band signals, respectively. Right: Wave height above which the scattering becomes diffuse, according to the Rayleigh criterion.*

### Equipment:

- Prototype P-band data grabber (volume <  30cm x 20 cm x 20 cm, weight < 5 kg)

- Dipole antenna (~60 cm stick-like antenna)

- Cables

- Pole where to subject the antenna

### Software tools used in this lecture:

1. OVL Portal and SEAscope

### Data sets used in this lecture:

None

### Key papers for background reading:


1. Seneviratne, et al., Section 11.7 in "Climate Change 2021 – The Physical Science Basis Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change", pp. 1513 – 1766, Cambridge University Press (2023), DOI: https://doi.org/10.1017/9781009157896.013
2. Zeng, L., and R. A. Brown, 1998: Scatterometer Observations at High Wind Speeds. J. Appl. Meteor. Climatol., 37, 1412–1420, https://doi.org/10.1175/1520-0450(1998)037%3C1412:SOAHWS%3E2.0.CO;2
3. Quilfen, Y., B. Chapron, T. Elfouhaily, K. Katsaros, and J. Tournadre, "Observation of tropical cyclones by high-resolution scatterometry", Journal of Geophysical Research  (1998), doi:10.1029/97JC01911.
4. Reul, N., J. Tenerelli, B. Chapron, D. Vandemark, Y. Quilfen, and Y. Kerr (2012), SMOS satellite L-band radiometer: A new capability for ocean surface remote sensing in hurricanes, J. Geophys. Res., 117, C02006, doi:10.1029/2011JC007474.

5. Mouche, A., et al., "On the Use of Doppler Shift for Sea Surface Wind Retrieval From SAR," in IEEE Transactions on Geoscience and Remote Sensing (2012), doi: 10.1109/TGRS.2011.2174998.
6. Zhang, B. and Perrie, W., "High Wind Speed Retrieval from Multi-polarization SAR", In: Li, X. (eds) Hurricane Monitoring With Spaceborne Synthetic Aperture Radar, Springer Natural Hazards Springer, Singapore (2017), doi:10.1007/978-981-10-2893-9_5.
7. Mouche, A., B. Chapron, B. Zhang and R. Husson, "Combined Co- and Cross-Polarized SAR Measurements Under Extreme Wind Conditions," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 55, no. 12, pp. 6746-6755, Dec. 2017, doi:https://doi.org/10.1109/TGRS.2017.2732508
8. Zavorotny, V.U., S. Gleason, E. Cardellach and A. Camps, "Tutorial on Remote Sensing Using GNSS Bistatic Radar of Opportunity," IEEE Geoscience and Remote Sensing Magazine (2014), doi: 10.1109/MGRS.2014.2374220.
9. Cardellach E, Nan Y, Li W, Padullés R, Ribó S, Rius A. "Variational Retrievals of High Winds Using Uncalibrated CyGNSS Observables", Remote Sensing (2020), doi:10.3390/rs12233930.
10. Cardellach, E.; Nan, Y.; Li, W.; Padullés, R.; Ribó, S.; Rius, A. Variational Retrievals of High Winds Using Uncalibrated CyGNSS Observables. *Remote Sens.* 2020, *12*, 3930. https://doi.org/10.3390/rs12233930


## 5.50. FIDUCIAL REFERENCE MEASUREMENTS (FRM): WHAT ARE THEY AND WHY ARE THEY IMPORTANT?

**Date and time:** 8th April 2025 16:30-16:50

**Lecturer:** Dr. Emma Woolliams (NPL, London)

**Aim of the lecture:** By the end of this lecture, you should understand the importance of uncertainty in the collection of Fiducial Reference Measurements at sea and have some tools to assess them.

**Objectives of the lecture:**

OBJ-1: understand SI traceability in the context of metrology

OBJ-2: understand how to estimate measurement uncertainty

**Abstract:**


Once on-orbit, the uncertainty characteristics of satellite instruments established during pre-launch laboratory calibration and characterisation activities and the end-to-end geophysical measurement retrieval process can only be assessed via independent calibration and validation activities. As noted in 1995 at the 20th Conference *Generale des Poids et Mesures* [RD-7], a recommendation was made that:

*''those responsible for studies of Earth resources, the environment, human well-being and related issues ensure that measurements made within their programs are in terms of well-characterized SI units so that they are reliable in the long term, are comparable world-wide*

*and are linked to other areas of science and technology through the world's measurement system established and maintained under the Convention du Metre''*.

This lays the foundation to relate satellite measurements to Systeme International d'Unites (SI) standards.

This lecture considers the application of metrological principles and traceability to SI for the satellite observations themselves, and the Climate Data Records derived from them, and also to Fiducial Reference Measurements (FRM) that are compared with the satellite observations.  For this purpose, the concept of Fiducial Reference Measurements (FRM) has been established as:

*"The suite of independent ground measurements that provide the maximum Return On Investment (ROI) for a satellite mission by delivering, to users, the required confidence in data products, in the form of independent validation results and satellite measurement uncertainty estimation, over the entire end-to-end duration of a satellite mission."*

The defining mandatory characteristics for FRM are:

i. FRM measurements have *documented SI traceability* (eg. via round-robin intercomparisons and regular (pre-and post-deployment) calibration of instruments) using metrology standards .

ii. FRM measurements are *independent* from the satellite geophysical retrieval process.

iii. An *uncertainty budget* for all FRM instruments and derived measurements is available and maintained,

iv. FRM *measurement protocols, procedures* and community-wide management practices (measurement, processing, archive, documents etc.) are defined, published openly and adhered to by FRM instrument deployments.

v. FRM are *accessible* to other researchers allowing independent verification of processing systems.

FRM are *required* to determine the on-orbit uncertainty characteristics of satellite geophysical measurements via independent validation activities. This lecture will review the foundation metrology principles that underpin SI traceability in the context of satellite measurements and the FRM that support them.

### Software tools used in this lecture:

None

### Data sets used in this lecture:

None

### Key papers for background reading:

1. GUM (2008): JCGM 100:2008 Evaluation of measurement data – Guide to the expression of uncertainty in measurement, report, and the GUM suite of documents: https://www.bipm.org/en/jcgm-wg1-publications
2. VIM (2008): JCGM 200:2012 International vocabulary of metrology - basic and general concepts and associated terms, https://www.bipm.org/documents/20126/2071204/JCGM_200_2012.pdf/f0e1ad45-d337-bbeb-53a6-15fe649d0ff1?version=1.8&download=true
3. Mittaz, J., Merchant, CJ., and Woolliams, ER. 2019. "Applying principles of metrology to historical Earth observations from satellites", Metrologia 56 032002. https://doi.org/10.1088/1681-7575/ab1705
4. [AD-4] Goryl, Philippe, Nigel Fox, Craig Donlon, and Paolo Castracane. 2023. "Fiducial Reference Measurements (FRMs): What Are They?" Remote Sensing 15, no. 20: 5017. https://doi.org/10.3390/rs15205017
5. QA4EO guidelines available at www.qa4eo.org
6. Donlon, C. J, P. Minnett, N. Fox and W. Wimmer, (2015), Strategies for the Laboratory and Field Deployment of Ship-Borne Fiducial Reference Thermal Infrared Radiometers in Support of Satellite-Derived Sea Surface Temperature Climate Data Records, in Zibordi., G,. C. Donlon and A. Parr (Eds.), (2015), Optical Radiometry for Oceans Climate Measurements, Vol. 47 Experimental Methods in Sciences, Elsivier, 697 pp., ISBN: 9780124170117

## 5.51. FIDUCIAL REFERENCE MEASUREMENTS OF SEA SURFACE TEMPERATURE

**Date and time:** 8th April 2025 16:50-17:10

**Lecturer:** Dr. Craig Donlon (ESA/ESTEC)

**Aim of the lecture:** By the end of this lecture, you should understand the importance of uncertainty in the collection of Sea Surface Temperature Fiducial Reference Measurements collected at sea.

**Objectives of the lecture:**

OBJ-1: to review how we estimate measurement uncertainty for SST measurements

**Abstract:** Fiducial Reference Measurements (FRM) are the suite of independent ground measurements that provide the maximum Scientific Utility (SU)/Return On Investment (ROI) for a satellite mission by delivering, to users, the required confidence in data products, in the form of independent validation results and satellite measurement uncertainty estimation, over the duration of the mission. The defining mandatory characteristics of an FRM are:

- FRM measurements have documented evidence of SI traceability via inter-comparison of instruments under operational-like conditions.
- FRM measurements are independent from the satellite SST retrieval process.

- An uncertainty budget for all FRM instruments and derived measurements is available and maintained, traceable where appropriate to SI ideally directly through an NMI
- FRM measurement protocols and community-wide management practices (measurement, processing, archive, documents etc.) are defined and adhered to.

FRM are required to determine the on-orbit uncertainty characteristics of satellite measurements via independent validation activities. "The process of assessing, by independent means, the quality of the data products derived from the system outputs". Validation is a core component of a satellite mission (and should be planned for accordingly) starting at the moment satellite instrument data begin to flow until the end of the mission. Without validation, the geophysical retrieval methods and geophysical parameters derived from satellite measurements cannot be used appropriately with confidence. In the case of the SST CDR, the concept of validation is not limited to the regular validation of a sample of SST retrievals from satellite instruments, but also to the stability of the derived time series over specified time and space scales. Stability is defined as the degree to which systematic effects in SST measurements are invariant over time.

This lecture will consider the importance of uncertainty budgets, the criteria for matching in situ data to satellite measurements followed by a discussion making FRM measurements at sea using different in situ (radiometer, underway pumped supply and hull mounted thermistor.

### Software tools used in this lecture:

None

### Data sets used in this lecture:

None

### Key papers for background reading:


1. Goryl, Philippe, Nigel Fox, Craig Donlon, and Paolo Castracane. 2023. "Fiducial Reference Measurements (FRMs): What Are They?" Remote Sensing 15, no. 20: 5017. https://doi.org/10.3390/rs15205017
2. Fiducial Reference Measurements for Satellite Temperature Product Validation. Available online: https://www.frm4sts.org/ (accessed on 16 October 2023).
3. Donlon, C. J, P. Minnett, N. Fox and W. Wimmer, (2015), Strategies for the Laboratory and Field Deployment of Ship-Borne Fiducial Reference Thermal Infrared Radiometers in Support of Satellite-Derived Sea Surface Temperature Climate Data Records, in Zibordi., G,. C. Donlon and A. Parr (Eds.), (2015), Optical Radiometry for Oceans Climate Measurements, Vol. 47 Experimental Methods in Sciences, Elsivier, 697 pp., ISBN: 9780124170117


## 5.52. FRM FOR SEA SURFACE SALINITY

**Date and time:** 8th April 2025 17:30-17:50

**Lecturer:** Dr Roberto Sabia (ESA/ESRIN)

**Aim of the lecture:** By the end of this lecture, you should understand the importance of uncertainty in the collection of Sea Surface Salinity (SSS) Fiducial Reference Measurements collected at sea, and the related impact on the satellite salinity validation metrics and representation errors.

**Objectives of the lecture:**

OBJ-1: To review different approaches to SSS FRM using the Salinity Pi-MEP Platform and embedded tools.

OBJ-2: To assess the various criteria for matching in-situ data to satellite measurements and related performance metrics.

OBJ-3: To characterize the satellite-vs-in-situ representation errors arising from the spatial (horizontal sub-footprint variability and vertical gradients) and temporal aliasing.

**Abstract:**

Ocean salinity is a key variable within the Earth's water cycle and a key driver of ocean dynamics. Through the advent of new observing technologies for salinity and the efforts to synthesize spaceborne salinity measurements with in-situ observations and numerical models, salinity science and applications have significantly advanced over recent years.

This Lecture will explore the broad set of in-situ salinity measurements available in the Salinity Pilot Mission Exploitation Platform (PI-MEP) and their usage for calibration and validation of satellite salinity missions (SMOS, SMAP and Aquarius) and multi-mission merged products (e.g. CCI-salinity).

Validation is a core component of a satellite mission, and only through that, the geophysical parameters derived from satellite measurements can be used with confidence.

Fiducial Reference Measurements (FRM) are a specific suite of independent ground measurements that provide the required confidence in data products, in the form of independent validation results and satellite measurement uncertainty estimation.

This lecture will consider the criteria for qualifying FRM salinity data, the importance of uncertainty budgets and the criteria for matching in-situ data to satellite measurements (and the related representation errors).

**Software tools used in this lecture:**

Salinity PI-MEP website (https://www.salinity-pimep.org/) and embedded tools

**Data sets used in this lecture:**

None

### Key papers for background reading:


1. Guimbard, S.; Reul, N.; Sabia, R.; Herlédan, S.; Khoury Hanna, Z.E.; Piollé, J.-F.; Paul, F.; Lee, T.; Schanze, J.J.; Bingham, F.M.; Le Vine, D.; Vinogradova-Shiffer, N.; Mecklenburg, S.; Scipal, K. & Laur, H. (2021) The Salinity Pilot-Mission Exploitation Platform (Pi-MEP): A Hub for Validation and Exploitation of Satellite Sea Surface Salinity Data Remote Sensing., 13(22):4600 https://doi.org/10.3390/rs13224600
2. Boutin, J., Yueh, S., Bindlish, R. et al. Soil Moisture and Sea Surface Salinity Derived from Satellite-Borne Sensors. Surv Geophys 44, 1449–1487 (2023). https://doi.org/10.1007/s10712-023-09798-5
3. Reul, N., S.A. Grodsky, M. Arias, J. Boutin, R. Catany, B. Chapron, F. D'Amico, E. Dinnat, C. Donlon, A. Fore, S. Fournier, S. Guimbard, A. Hasson, N. Kolodziejczyk, G. Lagerloef, T. Lee, D.M. Le Vine, E. Lindstrom, C. Maes, S. Mecklenburg, T. Meissner, E. Olmedo, R. Sabia, J. Tenerelli, C. Thouvenin-Masson, A. Turiel, J.L. Vergely, N. Vinogradova, F. Wentz, S. Yueh, Sea surface salinity estimates from spaceborne L-band radiometers: An overview of the first decade of observation (2010–2019), Remote Sensing of Environment, Volume 242, 2020, 111769, ISSN 0034-4257, https://doi.org/10.1016/j.rse.2020.111769


## 5.53. FRM FOR SYSTEM VICARIOUS CALIBRATION AND VALIDATION IN OCEAN COLOUR

**Date and time:** 8th April 2025 17:50-18:10

**Lecturer:** Dr Ewa Kwiatkowska (EUM)

**Aim of the lecture:** By the end of this lecture, you should understand the requirements for Fiducial Reference Measurements in Ocean Colour and be familiar with user resources, tools and guidelines

**Objectives of the lecture:**

OBJ-1: to review the specific FRM used for Ocean Colour System Vicarious Calibration

OBJ-2: to review radiometric FRM requirements, tools, and guidelines for Ocean Colour validation

**Abstract:**


Fiducial Reference Measurements (FRM) in satellite Ocean Colour are required for calibration and validation activities.

For calibration of satellite data, the Ocean Colour System Vicarious (OC-SVC) is needed to meet product radiometric and bio-optical requirements. This is because satellite instrument pre-launch and onboard calibrations cannot alone achieve the required water signal uncertainties and residual biases must be removed by calibrating against a highly accurate source of *in situ* measurements. OC-SVC is the Golden Standard in *in situ* FRM radiometry and requires specialised infrastructure and operational procedures.

FRM are further required to assert the conformance with the requirements for satellite Ocean Colour missions, as well as to provide dependable product validations and support algorithm development. A lot of progress has recently been made to develop guidelines, procedures and tools for the community to support it in the collection of FRM-quality *in situ* radiometric measurements. Training, supported *in situ* instrument calibrations, and instrument rental are also available.

**Software tools used in this lecture:**

None

**Data sets used in this lecture:**

None

**Key papers for background reading:**

1. Mission Requirements for Future Ocean-Colour Sensors, Reports of the International Ocean-Colour Coordinating Group (IOCCG), No. 13, Dartmouth, Canada, McClain, C. R., and G. Meister (eds.), https://ioccg.org/what-we-do/scientificworking-groups/report13
2. IOCCG White Paper System Vicarious Calibration (SVC) requirements for satellite ocean colour missions targeting climate and global long-term operational applications, https://ioccg.org/wp-content/uploads/2024/06/oc-svc-white-paper.pdf
3. https://www.eumetsat.int/OC-SVC
4. IOCCG Protocol Series, http://ioccg.org/what-we-do/ioccg-publications/ocean-optics-protocols-satellite-ocean-colour-sensor-validation/
5. https://frm4soc2.eumetsat.int/

## 5.54. FIDUCIAL REFERENCE MEASUREMENTS FOR OCEAN COLOUR: OLCI MATCHUPS WITH THOMAS

**Date and time:** 8th April 2025 18:10 – 19:00

**Lecturer:** Dr Hayley Evers-King (EUMETSAT) and Dr. Ewa Kwiatowska (EUMETSAT)

**Aim of the lecture:** To understand how to extract and appropriately analyse matchups between in situ and satellite data.

**Objectives of the lecture:**

OBJ-1: Understand the various choices that can be made to conduct satellite validation

OBJ-2: Use the ThoMaS toolkit to conduct matchup analysis with example (or students own) datasets.

**Abstract:**

This interactive lecture will include a demonstration of a Jupyter notebook showing how to conduct matchup analysis using the ThoMaS toolkit.ThoMaS is a Python based toolkit

that allows for extraction of data from multiple satellites, for comparison to input in situ data from a variety of common sources. It offers the opportunity to apply several matchup protocols with flexibility to account for different regional needs.

**Software tools used in this lecture:**

1. Jupyter Notebooks available from: https://gitlab.eumetsat.int/eo-lab-usc-open/ocean/sensors/learn-olci
2. Participants should follow instructions for local installation provided in the README, or be comfortable using a Binder implementation.
3. Participants should conduct a fresh git pull/test Binder just before the lectures.
4. Students can read more about the ThoMaS toolkit in the associated git repository https://gitlab.eumetsat.int/eumetlab/oceans/ocean-science-studies/ThoMaS/-/tree/main?ref_type=heads and the underlying matchup principles in the EUMETSAT matchup protocols: https://user.eumetsat.int/s3/eup-strapi-media/Recommendations_for_Sentinel_3_OLCI_Ocean_Colour_product_validations_in_comparison_with_in_situ_measurements_Matchup_Protocols_V8_B_e6c62ce677.pdf

**Data sets used in this lecture:**

1. Level-1 and 2 OLCI data from EUMETSAT.
2. Participants will need an eoportal account to access data from EUMETSAT – they can visit https://eoportal.eumetsat.int.

**Key papers for background reading:**

1. IOCCG (2008). Why Ocean Colour? The Societal Benefits of Ocean-Colour Technology. Platt, T., Hoepffner, N., Stuart, V. and Brown, C. (eds.), Reports of the International Ocean-Colour Coordinating Group, No. 7, IOCCG, Dartmouth, Canada. https://ioccg.org/wp-content/uploads/2015/10/ioccg-report-07.pdf
2. IOCCG (2009). Remote Sensing in Fisheries and Aquaculture. Forget, M.-H., Stuart, V. and Platt, T. (eds.), Reports of the International Ocean-Colour Coordinating Group, No. 8, IOCCG, Dartmouth, Canada. https://ioccg.org/wp-content/uploads/2015/10/ioccg-report-08.pdf

## 5.55. LIFE ABOARD THE TALL SHIP STATSRAAD LEHMKUHL

**Date and time:** 15th April 2025 14:00-14:20

**Lecturer:** Haakon Vatle, CEO Statsraad Lehmkuhl Foundation

**Aim of the lecture:** By the end of this lecture, you should understand how the Statsraad Lehmkuhl operates while at sea.

**Objectives of the lecture:**

OBJ-1: To understand the working environment of a tall ship

OBJ-2: To understand the watch system operated aboard the Statsraad Lehmkuhl

OBJ-3: To understand the meals and accommodation aboard the ship

## 5.56. PRACTICAL INFORMATION FOR JOINING THE SHIP

**Date and time:** 15th April 2025 14:30 – 14:50

**Lecturer:** Craig Donlon (ESA) and Haakon Vatle, CEO Statsraad Lehmkuhl Foundation

**Aim of the lecture:** By the end of this lecture, you should understand how to join the Statsraad Lehmkuhl while in port.

**Objectives of the lecture:**

OBJ-1: Where will the ship be when you arrive and how to get to it

OBJ-2: What to bring with you (and what not to bring)

OBJ-3: Opportunity to ask questions regarding joining the ship.

## 5.57. TALL SHIPS AND SPACESHIPS: AN ASTRONAUT PERSPECTIVE OF THE OCEAN

**Date and time:** 15th April 2025 15:00-16:00

**Lecturer:** Pablo Alveres Fernandez (ESA)

**Aim of the lecture:** By the end of this lecture, you should understand the importance of the ocean from an astronaut perspective

## 5.58. EXTENDED SESSION: PERSONAL SCIENTIFIC RESEARCH PLANS AND GROUPWORK

**Date and time:** 15th April 2025 16:00 -18:30

**Lecturer:** OCT Students

This is an interactive session, a last chance to review your research plans to be executed aboard the Statsraad Lehmkuhl before we join the ship.

# 6. INTRODUCTION TO YOUR LECTURERS

The team of lecturers has been composed of Principal Investigators and Scientists from leading universities and research institutions.

## 6.1. DR ALEJANDRO EGIDO, EUROPEAN SPACE AGENCY, ESTEC, THE NETHERLANDS

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**Alejandro** an Ocean and Hydrology Earth Observation Scientist in the Earth Surface and Interior Section at ESA' Mission and Science Division. With an engineering background, before joining ESA Dr. Egido was a Lead Scientist at the National Oceanic and Atmospheric Administration Laboratory (NOAA) for Satellite Altimetry in Washington, DC, USA. During his time at NOAA, he worked primarily on synthetic aperture radar (SAR) altimetry developing fundamental research and science products from SAR altimeter missions. He most notably developed fully focused SAR (FF-SAR) altimetry, a novel data processing technique that enables a drastic improvement in the along-track resolution of SAR altimeter data. Dr. Egido and his team then went on to develop science applications for this technique for the open ocean, sea ice and rivers and lakes. Before joining NOAA, he worked in the Space Department at Starlab Barcelona, Spain, developing research projects for ESA. Through these projects he was able to write his PhD Thesis on the topic "Global Navigation Satellite Systems Reflectometry (GNSS-R) for Land Remote Sensing Applications". He received his PhD, Cum Laude, from the Signal Theory and Communications Department of the Technical University of Catalonia, in Barcelona, Spain, in 2013. Dr. Egido studied telecommunications engineering and Master of Science at the University of Zaragoza, Spain, with specialisation in digital signal processing and microwave propagation.

## 6.2. PABLO ÁLVAREZ FERNÁNDEZ, EUROPEAN SPACE AGENCY

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**Pablo** holds a bachelor's degree in aeronautical engineering from the University of León (Universidad de León), Spain, and graduated with a master's degree in aerospace engineering from the Warsaw University of Technology (Politechnika Warszawska) in 2011. Next to his mother tongue Spanish, Pablo is fluent in English, Russian and French. Experience. After graduating university, Pablo was working as a structural engineer for several aircraft programmes, such as for Airbus and Safran in Spain, the UK and France between 2011 and 2017. From 2017 to 2020, while working as an ExoMars rover mechanical architect at Airbus Defence and Space in the UK, his responsibilities included the development of the radiosotope heater unit integration procedure in conjunction with Russian Space Agency ROSCOSMOS and ESA, as well as being a test director during the environmental test campaign. Furthermore, he was working on the design, development and testing of the different ExoMars rover bioseals to prevent biological contamination. Before being selected as an ESA astronaut candidate in November 2022, Pablo was working as Project Manager for Airbus operations in Spain. In this capacity, he was supporting different industrial projects across several Airbus plants. ESA experience. In November 2022, Pablo was selected as an ESA astronaut candidate. He commenced his one-year basic training programme in April 2023 and attained astronaut certification at ESA's European Astronaut Centre on 22 April 2024, rendering him eligible for spaceflight assignments.

## 6.3. DR. ANTONIO BONADUCE, OCEAN AND SEA ICE REMOTE SENSING GROUP, NERSC, NORWAY.

Dr. Antonio Bonaduce
Nansen Environmental and Remote Sensing Center, Geophyiscal Institute,
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**Antonio** is Research Leader of the Ocean and Sea Ice Remote Sensing Group at NERSC, in Norway. He has 15+ years of experience in sea-level research and satellite remote sensing in oceanography research. In particular, he has focused on the use of satellite altimetry to advance the understanding of sea-level variability and the role of mesoscale eddies and eddy-driven processes. In the last years he has focused on the mesoscale dynamics in the ocean resolved by the existing altimeter constellation and forthcoming wide-swath altimetry concept, as well as on ocean-wave current interactions. This has also included the synergy between satellite sensors and numerical models to disclose the 3D mesoscale field in the ocean at the regional scale. He is currently leading a strategic initiative to establish a sea-level prediction and reconstruction unit at the Bjerknes Center for Climate Research (Norway). Bonaduce is an affiliate member of the: (i) "Sea Level Rise" theme of the WCRP's Safe Landing Climates (SLC); (ii) JPI Knowledge Hub on Sea Level Rise initiatives; EuroGooS Scientific Advisory Working Group. He has also recently joined the ESA Sentinel-6 Next Generation Ad-hoc Expert Group.

## 6.4. MARYKE BEZUIDENHOUT OTC25 STUDENT LIASON

Maryke Bezuidenhout
Manguzi Hospital
South Africa

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Maryke is a physiotherapist who has spent 20 years at the rural coalface.in deep rural KwaZulu Natal, South Africa. Maryke was part of the One Ocean expedition Voyage in 2023 and will be the Liason point of contact for OTC25 students aboard the ship . She is currently the manager of an 18-strong multi-disciplinary rehabilitation team which works closely with local disability organizations and NPOs to provide comprehensive rehabilitation and disability services within the 8th most deprived district in South Africa. She has a post graduate diploma in health economics with distinction, as well as a strong public health background. When not advocating vociferously at policy level, or finding ever more innovative ways to sustain services within a crumbling system, she is probably full of grease repairing wheelchairs under a tree somewhere, tempting crocodiles and hippo in her kayak or scattering cattle on a remote single track on her mountain bike.

## 6.5. DR. EMMANUEL BOSS, PROFESSOR OF OCEANOGRAPHY, UNIVERSITY OF MAINE, USA

Dr Emmanuel Boss
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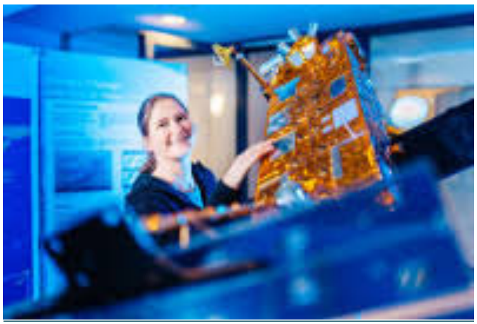
Emmanuel is a professor of Oceanography at the University of Maine where he has been since 2002. He is a coordinator of Tara Oceans. His lab has installed an in-line system measuring optical parameters of oceanic materials on the S/V Tara since 2009. He coordinated and taught in the Ocean Optics summer school in Maine from 2004-2023. He co-led the first science team for NASA's PACE satellite. He is involved in several PACE validation project as well as the calibration project, HyperNav, which uses profiling floats to obtain high quality radiometry calibration data for PACE. Emmanuel tends to do his science with friends. A long-term collaboration with Mike Behrenfeld has resulted in novel satellite algorithms (e.g. phytoplankton carbon, solar-stimulated fluorescence and its application to physiology) and in a new vision of the annual cycle of phytoplankton centered on the balance of growth and loss processes. His lab work with in-situ instrumentation focuses on developing methods for extracting as much information as possible from multiple instruments and validating them independently. These include works on particles and phytoplankton sizing, composition, aggregation, and phytoplankton functional types. Emmanuel and colleagues deployed the first profiling float with a chlorophyll and scattering sensors, documenting the NA annual cycle over 3yrs and which encouraged the inclusion of such measurements within the then upcoming BGC-Argo. Since, his lab has used BGC-Argo data in numerous studies to validate satellite products.

Prior to his current role, Emmanuel was postdoc and research faculty at Oregon State University for 4.5years. He obtained a PhD in physical oceanography at the University of Washington, USA, in 1997 and a MSc in Oceanography from the Hebrew University in

Jerusalem, Israel, in 1991. He obtained a bachelor's in physics, mathematics with a minor in atmospheric sciences from the Hebrew University in Jerusalem, in 1990.

## 6.6. PROF. DR. ASTRID BRACHER, ALFRED-WEGENER-INSTITUTE HELMHOLTZ CENTRE FOR POLAR AND MARINE RESEARCH (AWI), GERMANY



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**Astrid** is a professor of Environmental Physics at University Bremen and group leader on ocean optics and remote sensing at AWI. She is an expert for developing ocean color retrievals especially regarding the composition of phytoplankton groups across aquatic water bodies, combining different satellite sensor technologies. Further her group is focusing on  world-wide optical in-situ observations (more than 30 long ship-based expeditions in the last 15 years) for the development and validation of satellite retrievals and for improving the high resolution sampling of biogeochemical observations where satellite can not obtain data sets (e.g. under clouds). As scientific expert she advises DLR and ESA as part of the German satellite mission ENMAP and next generation Sentinel-3 optical mission advisory groups. She is regularly lecturing at University Bremen, is since 2014 the coordinator (and lecturer) of the Remote Sensing module within the yearly reoccurring Nippon Foundation Centre of Excellence Partnership for Observation of the Global Oceans (CoE-NF-POGO) and has been teaching at many summer school courses. Particularly she organized the North German marine institutes summerschool in 2019 on "Marine phytoplankton diversity observation: innovative methods and industrial applications". Astrid is enjoying data exploitation and crossing disciplines with the application of ocean colour products enabling to link to many key research areas in climate change research.

Prior to her current role, Astrid worked for 6 years as scientist linked to the ENVISAT mission on atmospheric sensors trace gas products validation at the Institute of Environmental Physics at the University Bremen. She obtained a PhD in biological oceanography from the University of Bremen, Germany, in 1999 and a diploma in biology from the University of Freiburg, Germany, in 1994.

## 6.7. PROF. STEPHEN BRIGGS, DEPARTMENT OF METEOROLOGY, UNIVERSITY OF READING

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After a PhD in Astrophysics and time as a University Physics lecturer, Stephen has enjoyed a career in satellite Earth observation spanning more than forty years. He was UK Director of EO before joining ESA in 2000, most of that time spent as Head of Department of EO Science, Applications and Future Technologies. In this he was responsible for exploitation of satellite data in science, climate, public sector services, civil security, environmental management and for developing commercial services. He was also responsible for the design, development and selection of new missions and instruments.

He currently holds a visiting Chair at Reading University Meteorology department and is attached to Cambridge University, where he is on the Board of the Centre for AI and Environmental Risk. He was Chair of the Global Climate Observing System from 2013 – 2019, responsible for ensuring the observations needed for support of the UNFCCC process and IPCC. He has attended many UNFCCC COPS, including the key meetings in Copenhagen (2010) and Paris (2015). He has worked with a wide range of organisations including WMO, CEOS, World Bank, Asian Development Bank, African Development Bank, UN-GFDRR, GEO, International Charter on Space and Major Disasters and many more. He is a reviewer of  EU Horizon projects, many related to climate emissions management, and is a member of the EU CO2 Task Force which oversees the ESA-EU CO2M Mission and related research. Recently he has been leading a European science team supporting the development of ESA's EO Science Strategy 2025-2040.

Stephen is a sailor, having sailed his own boat from UK to Italy before living aboard for several years in Rome, and enjoys skiing, golf and jazz, blues and classical music.

## 6.8. DR. ESTEL CARDELLACH, INSTITUTE OF SPACE SCIENCES (ICE-CSIC, IEEC)

Dr. Estel Cardellach

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**Estel** received the Ph.D. degree in physics from the Polytechnic University of Catalonia, Barcelona, Spain, in 2002. She studies scientific applications of Global Navigation Satellite Systems (GNSS) and other Sources of Opportunity (SoOp) for remote sensing of the earth. After postdoctoral positions at NASA/JPL (2003) and Harvard University - Smithsonian Center for Astrophysics (2004) she has been with the Institute of Space Sciences (ICE-CSIC/IEEC), Barcelona, Spain. She was Co-Chair of the Science Advisory Group of ESA's GEROS-ISS mission, and a Co-Principal Investigator of the G-TERN mission proposal (ESA EE9 Call). Currently, she is the Principal Investigator of the Radio-Occultation and Heavy Precipitation aboard the PAZ satellite and Co-Chair of the ESA's 2nd Scout mission (HydroGNSS) Science Advisory Group.

## 6.9. DR. BERTRAND CHAPRON, IFREMER, BREST, FRANCE

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**Bertrand** graduated from the Institut National Polytechnique de Grenoble in 1984 and received the Doctorat National (Ph.D.) in Fluid Mechanics in 1988. He spent three years as a post-doctoral research associate at the NASA/GSFC/Wallops Flight Facility, USA. He has experience in applied mathematics, physical oceanography, electromagnetic waves theory and its application to ocean remote sensing. He is currently responsible for the Oceanography from Space Laboratory, IFREMER.

## 6.10. DR. FABRICE COLLARD, OCEAN DATA LABORATORY, BREST, FRANCE.

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**Fabrice** graduated from the Ecole Centrale de Lyon in 1996, where he studied offshore engineering. In 2000, he received the PhD in oceanography and meteorology from Paris 6 University. His thesis was dedicated to the three-dimensional aspect of wind-wave field. He spent two years working on HF radars as a post-doctoral research associate at RSMAS, Miami, USA. He then joined IFREMER for the cal-val of the SAR Wave mode onboard ENVISAT.

Starting a small company, BOOST Technologies, with two other colleagues, he developed tools for wind/wave/current retrieval from SAR data before BOOST became the Radar Application Division of CLS of which he was head of the R&D department, working on the development and validation of surface wind, wave and current retrieval processor for ENVISAT and Sentinel-1. He then started in 2013 a new startup, OceanDataLab (https://www.oceandatalab.com) to develop tools and methods for analysis of Ocean Remote Sensing data, with an emphasis on exploiting the synergy between the different satellite/in-situ sensors for data-driven model development and numerical simulations validation.

## 6.11. DR. GARY CORLETT, EUROPEAN ORGANISATION FOR THE EXPLOITATION OF METEOROLOGICAL SATELLITES (EUMETSAT), GERMANY.

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**Gary** is a remote sensing scientist at EUMETSAT specialising in SST retrieval from SLSTR. He graduated from the University of Leicester in 1993 (B.Sc. Chemistry) and 1997 (Ph.D. Chemical Physics) and has 20-years' experience in remote sensing of both the Earth's atmosphere and surface. His current research interests are related to comparing satellite derived SST to in situ measurements over long time scales and understating the uncertainties throughout the process.

## 6.12. DR. BEN LOVEDAY, EUROPEAN ORGANISATION FOR THE EXPLOITATION OF METEOROLOGICAL SATELLITES (EUMETSAT), GERMANY (CONTRACTOR), GERMANY

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**Ben** has a master's degree in physical oceanography from the University of Southampton (2009) and PhD in numerical modelling of the Greater Agulhas system from the University of Cape Town (2014). He worked for several years at Plymouth Marine Laboratory as a marine Earth Observation scientist, gaining experience in using multiple remote sensing techniques - including ocean colour, SST, altimetry and SAR. Ben has contracted for

EUMETSAT since 2019, and currently runs their Copernicus Marine Training Service. He can be contacted for any questions about the EUMETSAT Copernicus marine data stream.

## 6.13. DR. CRAIG DONLON, EUROPEAN SPACE AGENCY, ESTEC, THE NETHERLANDS

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**Craig** received a Ph.D. Oceanography (1994) Department of Oceanography, University of Southampton, UK and a B.Sc. First class (Hon) in 1998 at Department of Environmental Science, University of Lancaster, UK. He worked at the Met Office UK for 5 years in the operational Oceanography department, at the University of Colorado, USA as an Assistant Research Professor, and at the European Commission Joint Research Centre Italy for 5 years. His main interests are air-sea interaction processes seen from remote sensing of oceans and ice. He currently leads the Earth Observation System Architecture Office at the European Space Agency.

## 6.14. DR. MARK DRINKWATER, EUROPEAN SPACE AGENCY, ESTEC, THE NETHERLANDS

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**Mark** leads the European Space Agency's Earth and Mission Science Division where he is responsible for the scientific support to preparing, developing and operating ESA's Earth observation satellite missions. He is also Senior Advisor on polar science and related climate issues.

Mark graduated from the University of Durham in 1984 and completed a PhD at the Scott Polar Research Institute at the University of Cambridge in 1987. During his combined career at NASA/Jet Propulsion Laboratory and ESA, he contributed to the design, development and success of research and operational satellite missions such as Topex/Poseidon, ERS-1/2, Envisat, QuikScat, MetOp, CryoSat, SMOS, GOCE, and the Copernicus Sentinels – leading pioneering scientific research activities using their data. After a research career and participation in many research expeditions and campaigns to both poles, he later orchestrated the support of 15 space Agencies to the International Polar Year research, and later Chaired the WMO's Polar Space Task Group. Most recently he represented ESA at the inaugoral Paris *One Planet Polar Summit* and lead the development of ESA's new Earth Observation Science Strategy "*Earth Science in Action for Tomorrow's World*".

## 6.15. DR FLORIAN LE GUILLOU, DATALAS, FRANCE

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I obtained a Master's degree in Aerospace Engineering from ISAE-SUPAERO in Toulouse in 2018, specializing in Earth observation, space sciences, and orbital satellite conception and operation. During my studies, I completed two six-month internships as a scientific engineer at private companies. The first was at Reuniwatt in La Réunion, France, where I worked on high-resolution short-term forecasting of cloud cover and solar irradiation from geostationary satellite images. The second was at Noveltis in Toulouse, France, where I implemented inverse methods to estimate greenhouse gas emissions from spectro-imaging satellite observations.

In 2018, I began a PhD in physical oceanography at the Institut des Géosciences de l'Environnement (IGE) in Grenoble, France. My research focused on merging satellite altimetry observations to prepare for the scientific exploitation of the CNES/NASA SWOT satellite mission.

As an intern fellow researcher at the ESA Science Hub, I am extending the work from my PhD by using data synergies among European satellites to improve estimates of ocean circulation at fine spatial and temporal scales. My primary focus is on implementing physically constrained inverse methods to estimate upper-layer ocean currents from satellite observations of sea surface height, temperature, and ocean color. I design ocean models, such as those resolving quasi-geostrophic and advection-diffusion equations, and develop inversion methods based on 4D-Variational Assimilation and Deep Learning techniques. The experimental methods are mainly tested in real setups in the North Atlantic Ocean and the Mediterranean Sea, and are compared to operational products.

Additionally, I am involved in the ESA Sentinel-3 Next Generation Topography expert team, where I study the benefits of wide-swath altimetry data, such as that provided by the recently launched NASA/CNES SWOT mission, for observing ocean dynamical features at scales below 100 km in wavelength.

In a broader view, since my PhD, I have been a strong advocate for open science and continue to develop open-source, well-documented codes for the community.

## 6.16. DR. HAYLEY EVERS-KING, EUROPEAN ORGANISATION FOR THE EXPLOITATION OF METEOROLOGICAL SATELLITES (EUMETSAT), GERMANY

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**Hayley** is the lead marine applications expert at EUMETSAT in the User support and Climate Services division. She provides user support and training on ocean applications of satellite data and manages feedback between user(s) and operational satellite agencies, mostly in support of the European Commission Copernicus Programme. Her research background covers the use of optics to derive information about the oceans. She has worked throughout the satellite data value chain from the validation of satellite sensor measurements to algorithm development and data use for various applications including harmful algal blooms and water quality services for aquaculture, ocean heat flux, carbon pools, climate model validation and marine spatial planning. She is a keen programmer, focusing exclusively on open-source tools, and a passionate science communicator seeking novel ways to use new media to share science with new satellite data users and the public.

Prior to her current role, Hayley worked for 5 years as a Marine Earth Observation Scientist at Plymouth Marine Laboratory. She obtained a PhD in ocean remote sensing from the University of Cape Town, South Africa in 2014.

## 6.17. DR. LUCILE GUALTIER, OCEAN DATA LABORATORIES, BREST, FRANCE

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**Lucile** graduated from a general engineering school (ENSTA, Ecole Nationale des Techniques Avancées, with a specialization in environment) in 2009. She received her PhD in 2013 on Improving the estimation of ocean surface currents using sea surface temperature and chlorophyll high resolution images. She spent two years at JPL (Jet Propulsion Laboratory, NASA / Caltech, Pasadena, US) working on using the synergy of remote sensing observation to improve the estimation of the surface of the ocean. She has also been involved in the scientific definition of the SWOT mission, which is an innovative mission aiming at measuring ocean surface dynamic at high resolution.

In late 2015, she has joined OceanDataLab and she is now a Research Engineer, working on improving the reconstruction of ocean surface current using various remote sensing data as well as on the use of the synergy of data and Lagrangian diagnostics to improve our understanding of the ocean surface dynamics.

## 6.18. ROGER HAAGMANS, EUROPEAN SPACE AGENCY, ESTEC, THE NETHERLANDS (RETIRED)

Roger Haagmans
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**Roger** studied geodetic engineering at the Delft University of Technology in the Netherlands. He was employed at first as research scientist and later as assistant professor at the Faculty of Geodetic Engineering, Delft University of Technology. Next he took the position of associate professor at the Department of Mapping Sciences at the Agricultural

University of Norway. His main interests were geodesy, gravity field studies from terrestrial, airborne and dedicated satellite gravity missions (GOCE, GRACE) and satellite altimetry (Seasat, Geosat, TOPEX/Poseidon, ERS-1,2, Envisat) and its geophysical and oceanographic applications, land-sea height systems and marine geodesy and hydrography. He also worked on wave propagation aspects of acoustic signals for bathymetric applications and efficient use of systems.

In 2001 he joined ESA as principal scientist solid earth and as Head of the Solid Earth unit of the Earth Science Division. Since 2008 he is head of the Earth Surfaces and Interior section of the Earth and Mission Science Division in the Science, Applications and Future Technologies Department of the Earth Observation Programmes Directorate. He has been responsible for mission science support throughout implementation of ESA's GOCE and Swarm Earth Explorers. He was also involved in studying new concepts for future missions as mission scientist for the NanoMagSat, Hydroterra and ESA's next generation gravity mission. In addition, he has (co-) authored over 90 scientific articles on various scientific topics. In addition, he has (co-) authored over 100 scientific articles on a wide range of scientific topics.

## 6.19. PROF. JOHNNY JOHANNESSEN, NERSC, BERGEN, NORWAY

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**Johnny** has 30 years experience in satellite remote sensing in oceanography and sea ice research. In particular, he has focused on the use of synthetic aperture radar (SAR) to advance the understanding of mesoscale processes along the marginal ice zone and along open ocean fronts and eddies. Johnny has participated in 15 international field campaigns and has been chief scientist on 10 of these cruises, predominantly in the Arctic Marginal Ice Zones and in the Norwegian Coastal Current. In the last 15 years he has also been involved in development and implementation of operational oceanography both at national and international level. Johnny has authored/co-authored more than 200 scientific and technical publications, reports and book articles of which 90 papers are published in International Review Journals and 22 are published as peer review book articles.

Johnny Cand. Real from University of Bergen in 1979. Dr. Philos from University of Bergen in 1997. Research Director in Ocean Remote Sensing, Nansen Environmental and Remote Sensing Center, Vice director Nansen Environmental and Remote Sensing Center since 2010. Associate Professor at the Geophysical Institute, University of Bergen since 2002.

## 6.20. DR. ANTON KOROSOV, NERSC, NORWAY

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**Anton** received a PhD in oceanography from the State University of Hydrometeorology in St. Petersburg, Russia in 2007. He first worked with optical remote sensing of ocean color at the Nansen Center in St. Petersburg and then moved to Bergen in 2010 to start working at NERSC.

Anton works primarily with SAR remote sensing of sea ice for studying sea ice dynamics. He develops automatic algorithms for ice drift and ice type retrieval using conventional computer vision techniques and employing new machine learning approaches. He also develops algorithms combining PMW-derived ice concentration and drift for climate data records of sea ice age. Anton is a member of Sea Ice Modelling group at NERSC and his activities are closely relate to development and improvement of the next generation sea ice model (NeXtSIM). He developed methods for assimilation of sea ice deformation into neXtSIM and new methods for tuning neXtSIM parametrization using Lagrangian ice motion and deformation datasets.

## 6.21. EWA KWIATKOWSKA, EUROPEAN AGENCY FOR THE EXPLOITATION OF METEOROLOGICAL SATELLITES (EUMETSAT)

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**Ewa** works as a Senior Remote Sensing Scientist and the Lead of the Ocean Colour Team. She has over 20 years of experience with Ocean Colour data, in calibration and validation, algorithm development, and applications, first as a Post-Doctoral Fellow at the Japanese Space Agency's Earth Observation Research Center, then with NASA's Ocean Colour Project, European Space Agency ESTEC, and with EUMETSAT. Ewa received the Masters degree in mathematics and a second one in computing, and a Ph.D. degree in machine learning. She extended her academic background through graduate courses in remote sensing, radiative transfer, wave propagation, optics, and lasers. She is passionate about Ocean Colour observations of the tiny little phytoplankton, which enabled the life as-we-know-it and are still continuously fundamental to our planet.

## 6.22. ARTEM MOISEEV, PHD, RESEARCHER AT OCEAN AND SEA ICE REMOTE SENSING GROUP, NERSC

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**Artem** is a physical oceanographer. He obtained his PhD in ocean remote sensing from the University in Bergen (Norway) in 2021, while employed at the Nansen Center, working with satellite data to improve how to detect ocean surface currents from space. Artem studies upper ocean dynamics, ocean-atmosphere, and wave-current interactions using synergy of satellite and in-situ observations and models. His main interest is in developing new solutions for observing ocean wind, waves, and surface currents from satellite Synthetic Aperture Radars. His main expertise is with Doppler shift observations from

Sentinel-1 where he has been developing retrieval algorithms for retrieving ocean surface currents, signal calibration, and product validation. He also has experience geospatial data processing and analysis, and machine learning.

## 6.23. DR KAT MORRISEY SOUTH AFRICAN ENVIRONMENTAL OBSERVATION NETWORK (SAEON), UNIVERSITY OF CAPE TOWN

Dr. Kat Morrisey
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**Kat** is a passionate marine microbial ecologist with a hands-on approach to oceanographic research. She earned her Ph.D. in Marine genetics from Ghent University in Belgium, where she developed a deep interest in understanding the intricate dynamics of marine ecosystems. She specializes in marine microbial ecology and environmental genetics both in coastal and offshore ecosystems. She has extensive experience in the field, and aboard research vessels, collecting and analyzing samples from various oceanic regions. Kat is currently a Postdoctoral Research Fellow at the South African Environmental Observation network (SAEON) and the University of Cape Town, where she is dedicated to exploring and understanding the ocean's microbial life.

## 6.24. SEJAL PRAMLALL, UNIVERSITY OF BERGEN, NORWAY.

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**Sejal** is a PhD student in the Marine Optics group at the University of Bergen. She has an interest in improving the utility of satellite ocean colour data through in situ data collection, satellite product validation and algorithm development. She holds a BSc in Marine Biology, Ocean & Atmosphere Science, and Environmental & Geographical Science, along with a BSc Honours in Ocean & Atmosphere Science from the University of Cape Town. Her research on polar storm tracks crossing the Antarctic Marginal Ice Zone led her to participate in a 6-week Antarctic expedition aboard the SA Agulhas II as part of the sea-ice team.

In 2023, Sejal completed her MSc in the Spectral Remote Sensing Laboratory at the University of Victoria, Canada, where she validated merged Chlorophyll-a products in North Pacific coastal waters and explored phytoplankton phenology patterns using bioregionalization and unsupervised clustering analysis.

Her experience in ocean colour remote sensing was further strengthened by attending several programs, including the IOCCG Summer Lecture Series (2022), the Ocean Optics Class in Maine (2023), and the previous Advanced Ocean Synergy Training Course (2023) as part of the Ocean Biology group. With a strong passion for science communication, Sejal is eager to share her knowledge and experiences related to ocean colour satellites with the next cohort of students.

## 6.25. DR. NICOLAS REUL, IFREMER, LABORATOIRE D'OCÉANOGRAPHIE SPATIALE, TOULON, FRANCE

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**Nicolas** is a research scientist at IFREMER focussing on the development and exploitation of satellite passive microwave measurements including ESA SMOS, NASA SMAP and the Copernicus Imaging Microwave Radiometer (CIMR). See http://annuaire.ifremer.fr/cv/16746/en/ for a full bibliography of papers and activities.

## 6.26. DR MARIE-HÉLÈNE RIO, EUROPEAN SPACE AGENCY, ESRIN, ITALY

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**Marie-Hélène** is a senior scientist. She holds a space engineering degree plus a PhD in physical oceanography and has a 20 year long experience in altimeter data analysis and validation, and in space and in-situ data synergy for calculating added-value ocean products. She spent most of her scientific career at CLS, a subsidiary company from the French Space Agency (CNES), where she carried out seminal work on the estimation of the ocean Mean Dynamic Topography and mean geostrophic surface circulation from the combination of space (altimetry, gravimetry, SAR) and in-situ (drifters, T/S profiles) data. She has also worked on estimating the Ekman response to the wind forcing by developing empirical models based on the combination of altimeter, wind and drifter data. Recently she has been working on innovative algorithms for calculating the ocean surface currents from the synergy of altimetry and Sea Surface Temperature or Ocean Color images. In 2018 she joined the Science, Applications & Climate Department from the European Space Agency, where she develops and manages ocean science and application projects covering a wide range of topics such as upper-ocean dynamics, marine carbon cycle, water quality, ocean extreme events, marine biodiversity, ocean health, etc

## 6.27. DR SASKIA RÜHL, PLYMOUTH MARINE LABORATORY, PLYMOUTH, UNITED KINGDOM

Dr Saskia Rühl,
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**Saskia's** original background was in Marine Biology, but she has since broadened her interests to include a mix of marine ecology, biochemistry, oceanography and geophysics. Her aim is to gain a better understanding of vertical fluxes in marine environments in general, and the biological carbon pump in particular.

She carried out her doctoral studies between 2016 and 2020 at Plymouth Marine Laboratory and Southampton University, focussing on exchanges of dissolved and particulate matter between the seafloor and the water column on different time scales. Following this she worked as a postdoctoral researcher at the Helmholtz Zentrum Hereon in Geesthacht, Germany, using plankton and particle imagers to study the role of both in the biological carbon cycle.

Throughout this postdoctoral work, Saskia became interested in, and acquainted with, digital methods such as machine-learning image classification, and automated sensors. In her job as a Digital Marine Biologist at PML, Saskia aims to tackle the challenges of marine science by combining classical sampling techniques with state of the art sensing and data processing methodologies and technologies.

## 6.28. ANNA RUTGERSSON, PROFESSOR OF METEOROLOGY AT UPPSALA UNIVERSITY.

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Anna brings her enormous expertise in air-sea interactions, air-sea gas exchange, atmospheric boundary layer and turbulence processes, eddy-covariance observations and combining in-situ data with EO and modelling to the #OTC25. Prof. Rutgersson is the PI of the ICOS field station Östergarnsholm in the Baltic Sea. She is member of the SSG in Baltic Earth and a previous member of the SOLAS SSC as well and Baltic Earth SSG. Member of the ESA Advisory Council for Earth Observation (ACEO).

## 6.29. DR. ROBERTO SABIA, EUROPEAN SPACE AGENCY, ESRIN, FRASCATI, ITALY.

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**Roberto** was born in Napoli, Italy, in 1975. He graduated cum laude in Environmental Sciences, curriculum in Oceanography, at Universitá Parthenope in Napoli, Italy (2002), and obtained the Ph.D. cum laude in Signal Theory and Communication at Universitat Politecnica de Catalunya (UPC) in Barcelona, Spain (2008), with a Thesis on the ocean salinity retrieval applied to the ESA Soil Moisture and Ocean Salinity (SMOS) mission.

In 2006, he was visiting Ph.D. student at NOC, Southampton, UK. From 2010 to 2013, he was an ESA post-doc Research Fellow at ESA-ESRIN, Frascati, Italy. In 2013, he was with Telespazio-UK Ltd. seconded at ESA-ESTEC, Noordwijk, the Netherlands, and since 2015 at ESA-ESRIN, Frascati, Italy, with coordination responsibilities on several oceanographic projects. In 2023, he has been appointed Earth Observation Ocean Scientist at ESA-ESRIN, Frascati, Italy. In 2008, he was the recipient of the best Ph.D. award in Remote Sensing of the European IEEE GRS Society. In 2010, he has led a European COST Action proposal titled "SMOS Mission Oceanographic Data Exploitation (SMOS-MODE)", successfully funded for the period 2011-2015. In 2018 he obtained the APM Project Management Qualification (PMQ). His research interests are within the ocean remote sensing and climate change domains - specifically on ocean salinity, carbon cycle and ocean acidification.

## 6.30. PROF. ANDREW SHEPERD, UNIVERSITY OF NORTHUMBRIA, UK

Prof. Andrew Sheperd,
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**Andy** is Head of the Department of Geography and Environment at Northumbria, Director of the NERC Centre for Polar Observation and Modelling, Principal Scientific Advisor to the European Space Agency's CryoSat satellite mission, co-leader of the ESA-NASA Ice Sheet Mass Balance Inter-comparison Exercise, and a contributing author to IPCC assessment reports. He uses satellites to study Earth's climate, and his main contributions to science have involved developing remote observations of the cryosphere - especially using radar altimetry. He has led field campaigns in Europe, Africa, the Arctic, and in Antarctica to calibrate and validate satellite sensors. He studied in the Department of Physics and Astronomy at the University of Leicester, and he has held academic posts at University College London and the Universities of Cambridge, Edinburgh, and Leeds.

## 6.31. PROF. JAMIE SHUTLER, UNIVERSITY OF EXETER, UK

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**Jamie** is an ocean and atmospheric scientist with a wide range of interests that exploit satellite Earth observation, in situ observations and models to study and monitor land, water and atmosphere environments and interactions, particularly in relation to climate. This includes studying atmosphere-ocean exchange of climatically important gases, carbon accounting, bacterial, biological, viral and chemical water quality and land-water continuum interactions. His work has covered novel in situ monitoring methods to support aquaculture, through to global analyses of carbon to support policy, through to the design of satellites for the European Space Agency. He was an invited scientific reviewer for the Intergovernmental Panel on Climate Change (IPCC) Special Report on the Oceans and Cryosphere in a Changing Climate (SROCC), and he was a lead author for the United Nations Educational, Scientific and Cultural Organisation (UNESCO) and International Oceanographic Commission (IOC) decadal vision for integrated ocean carbon research. His research has been featured in the Guardian Environment, BBC news, Al Jazeera TV, Forbes, Higgs, The Daily Mail, The World Economic Forum, contributed to UK parliamentary enquiries (Ocean Acidification, 2017; Sustainable Seas, 2018) and guided international and inter-governmental agencies and research programmes. His research team (JamieLab) currently comprises 3 post-doctoral researchers. All of the JamieLab research software is open source and freely available and this includes the FluxEngine python toolbox for calculating atmosphere-ocean gas fluxes.

## 6.32. HAAKON S. VATLE, CEO OF THE FOUNDATION OF THE NORWEGIAN TALL SHIP STATSRAAD LEHMKUHL, AND EXPEDITION LEADER FOR THE ONE OCEAN EXPEDITION

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**Haakon** currently hold position as the CEO of the foundation of the Norwegian tall ship Statsraad Lehmkuhl, and expedition leader for the One Ocean Expedition. He started his career on Statsraad Lehmkuhl as deck apprentice in 1996 and sailed on board every season until 2005. During these years, he did parallel university studies within psychology, organisational psychology and also fulfilled a teachers degree and a master’s degree in music (the master was about shanties and seasongs).

From 2005 to 2016 he organized and was project manager for big maritime and music festivals in Bergen, Stavanger and Stord (The Tall Ships Races 2008 Bergen, The Tall Ships Races 2011 Stavanger, The Tall Ships Races 2014 Bergen, The International Hanseatic Days Bergen 2016, Stordfest 2007,2010,2013).

In 2016 he returned to Statsraad Lehmkuhl as CEO and immediately started the planning of One Ocean Expedition 2021 – 2023, a 20 month circumnavigation of the globe and a recognized part of the UN´s Ocean Decade. The expedition became a huge global success, and initiated the One Ocean Week in Bergen. It changed the course of the ship in many matters, and is the reason for the upcoming One Ocean Expedition 2025 – 2026. Haakon has a noticeable global network within Ocean matters and is a highly sought speaker for these topics.

Haakon is also a professional musician and lead singer in Storm Weather Shanty Choir (est. in 2000) who tours worldwide.

## 6.33. DR KARINA VON SCHUCKMANN (HDR), MERCATOR OCEAN INTERNATIONAL, FRANCE

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**Karina** is a physical oceanographer specialized in ocean climate monitoring working at Mercator Ocean International, France. Passionate about the ocean, her interest lies in understanding the role of the ocean – and its interaction within – in the Earth's climate system, its changes and underlying processes involved, and how they can be best observed (in situ, remote sensing), monitored (reanalyses and operational systems) and estimated (analyses approaches, ocean indicator development) in support of a sustainable future development. She is an expert of the Earth heat inventory, which is to a large extent (~90%) determined by heat storage in the ocean, and which provides a measure on how far the Earth system is out of energy imbalance, and how fast anthropogenic heat is accumulating in the Earth's climate system. She is – alongst others - the Director of the Copernicus Ocean State Report, which provides regular and state-of-the-art knowledge on the state, variability and change of the ocean at an annual basis. She was lead author of IPCC SROCC and AR6 (Working Group I); a principal author of the WMO State of the Climate; she contributed to the recent IOC Global Ocean Science Report, and she is currently lead author for the World Ocean assessment. She is a member of several international expert panels, such as the GCOS/GOOS OOPC panel, and the ESA Climate Science Advisory Board. She is a member of the European Academy of Science and laureate of the climate price of the French Academy of Science in 2023.

## 6.34. DR EMMA WOOLIAMS, NATIONAL PHYSICS LABORATORY, UK

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**Emma** graduated from Imperial College London in 1998 and has worked as a metrologist at the National Physical Laboratory since then. Her PhD was on the establishment of the UK's primary spectral irradiance scale. In her early career, she worked as a laboratory metrologist specialising in radiomety and thermometry, and conducting international comparisons to ensure SI consistency. This naturally led to work on radiometric satellite sensors - first for pre-flight calibrations, then for ways of calibrating satellites in orbit. She was the lead metrologist on several projects that, for the first time, established rigorous methods for determining and validating uncertainties in satellite sensors post-launch. Having established a successful team of scientists who focus on applying metrology approaches to a wide range of radiometric sensors, Emma has now switched her focus to radar satellites. Emma Woolliams is also chair of the European Metrology Network for Climate and Ocean Observation.

## 6.35. DR. ZIAD EL KHOURY HANNA, OCEAN DATA LAB, FRANCE

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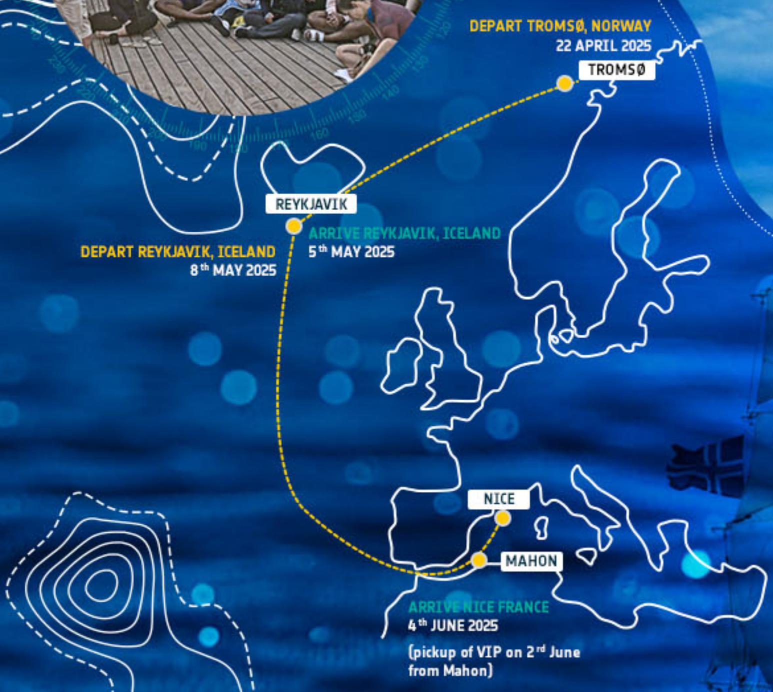
**Ziad** holds an engineering degree in Computer Science from the Ecole Nationale d'Ingénieurs de Brest (ENIB), France. In 2015 he joined OceanDataLab as software engineer, where he designed and developed a large part of the websites hosted by ODL, which he now maintains. He is also responsible for the design, development and integration of web visualization and analysis tools for ocean data (OVL Portal and

SEAScope) as well as the new online sharing platform SEAShot accessible from the Ocean Virtual Laboratory (OVL) web portal.

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