

Trip Report from ESA Advanced Training on Ocean Remote Sensing and Synergy 11-15 September 2017

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Location: FCUP, University of Porto, Porto, Portugal;
Dates: 11/09/17-15/09/17

PURPOSE

- 1) To learn about remote sensing for oceanography, science, satellite data utilization, and software
- 2) To understand fundamentals of oceanography and remote sensing and thinking how it may be applied to NTNU SmallSat mission
- 3) To network in the international scientific community with emphasis on academia, institutions and businesses at lectures and interactive lectures as well as at evening gatherings and events.
- 4) Being introduced to the community and most importantly learn about up-to-date topics in relevant domains such as in hyperspectral imaging for ocean color, SAR, altimetry related to our NTNU SmallSat project.
- 5) Connecting with key people inclined for collaboration.
- 6) Meet Joao B. Sousa at FEUP, extend discussions about future collaboration efforts for our SmallSat. Also visit his AUV/UAV lab and be introduced to LSTS toolchain and connect with the folks there.
- 7) Meet Jose B.C. da Silva, present our NTNU SmallSat concept and gain his interest on how it may be applied to his research.
- 8) Meet with Renato Mendes and gain his interest in HSI for our NTNU SmallSat application(s).

OVERVIEW

This report includes detailed daily summaries and list of lectures during the training course, following a short summary with regards to notable persons connected with, a list of relevant institutions, and finally follow-up actions. I will not cover detailed material presented in the lectures or interactive lectures, this can otherwise be found in document "Practicals Sessions Manual" which can be found on Google Drive. I have also uploaded all lectures to the drive.

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MONDAY 11TH AUGUST - DAY 1 START

Highlights

Start of course; met with **Jose C.B. da Silva**; met with **Joao B. Sousa** and his team at FEUP; met with **Renato Mendes** lecture about phytoplankton by **Vanda Brotas**; interactive lectures on ocean color, atmospheric corrections and SST.

Summary

- 1) Lectures and interactive lectures (see below).
- 2) Themes of this day were:
 - Satellite ocean synergy. The general picture of why oceanography is important.
 - Intro to the functionalities of software.
 - Learn to observe meso-scale and sub meso-scale ocean surface structures using Sea Surface Temperature (SST) and Ocean Colour data sets and better represent the polar oceans.
 - Using Sentinel-1 SAR images: sea surface roughness, waves.
 - Using data from Sentinel-2 Multi-Spectral Imager and Sentinel-3 Ocean and Land colour imager (OLCI) and altimeter.
 - Phytoplankton and ocean colour (Copernicus data - OC-CCI data).
 - Calculate an Chlorophyll index from OLCI L1 data.
 - Combine ocean color and SST/ocean heat to see interactions.
- 3) Introduced myself during a short coffee break to **Jose C.B. da Silva**, who was one of those arranging the ESA course at FCUP.
 - We decided to talk later on during the course, since there was little time and he had a lot to do (busy).
- 4) Also met with **Renato Mendes** from UPorto and talked about our NTNU HSI SmallSat. He is interested, especially for application to river plumes (the non-biological applications of hyperspectral imaging).
- 5) Lecture: "Phytoplankton dynamics from Space" by V. Brotas and the following interactive lecture on ocean colour. Important but did not have the chance to properly talk with her unfortunately.
- 6) Met with **Joao B. Sousa at FEUP, University of Porto** for 45 min during course lunch break where he took me for a buffet close to FEUP.
 - I explained to him first of all about our NTNU SmallSat project and HSI imager
 - He expressed great interest in collaborating and providing testing facilities for our HSI on drones. This would entail testing in at the port of Porto, the Azores and Madeira.
 - His faculty will start a *systems engineering* course at FEUP for undergraduate students in the week of 18th September. He thought about how we may aid in this (also me with my systems engineering background to provide guidance, inputs to methodology, and examples). A good project for them would be how to design a HSI or Ground Station. I am interested in aiding.
 - In case of a NTNU SmallSat flight, we talked about potential usage of ground station in University of Porto. They might build a ground station accommodating UHF/VHF or even S-band. We should talk further about this. If we want a low-latitude first flight, this might be a solution when observing a target area in e.g. the Azores.
 - He showed me his lab and introduced me to Joao Pereira and Paulo (?). Great to see the work on UAVs and AUVs (with pretty side-scanning echo sounders).
- 7) Unfortunately missed half of interactive lecture "Investigating the colour of the ocean from space" it due to meeting with Joao Sousa and traffic, but stepped in and worked with **Antoine Ndende Ba from University of Rennes 2 in France** and **Sam Edward Hunt from National Physical Laboratory in UK**. These became very close companions and friends during my whole stay. Antoine Ndende Ba did his PhD in Hyperspectral imaging including work on atmospheric corrections. Worth to extend talks.
- 8) Icebreaker and Student Introductions. Not really group work that happened here, but some brainstorming. Trying to find those who share same interests for group work. Agreed with **Renato Mendes** to bring out people for social event.

- 9) Dinner and drinks with Renato, Antoine, Samuel, **Julia Claire Haywood** - biologist and tracking marine turtles through satellites, and the Romanians **Marius Budileanu and Ionut Serban** from University of Bucharest who are studying river plumes and deltas from space.

Lectures (please see NTNU SmallSat Google Drive)

- Lecture 1 "Measuring the ocean using different satellite instruments in synergy"
- Lecture 2 "Phytoplankton dynamics from Space" by **Vanda Brotas, University of Lisbon**.

Interactive lectures (please see NTNU SmallSat Google Drive)

- Interactive Lecture 1: "Exploring the ocean mesoscale and sub-mesoscale using thermal and optical imagery".
- Interactive Lecture 2 "Investigating the colour of the ocean from space" (relevant)
- Interactive Lecture 3 "Investigating the temperature of the ocean from space"

Software used

- SNAP (<http://step.esa.int/main/toolboxes/snap/>), great for ocean color!
- Ocean Virtual Lab (OVL) which is open-source (<https://ovl.oceandatalab.com/>), multi-purpose.
- SeaScope (works only on Linux OS). Good tools to use for everything (ocean color as well), multipurpose and doesn't need web-loading like OVL..

TUESDAY 12TH AUGUST - DAY 2

Highlights

Interactive lectures on altimetry, ocean heat, and modeling of ocean currents; **AUV drone demonstration** at the port of Porto; further talks with **Jose da Silva**.

Summary

- 1) Lectures and interactive lectures (see below).
- 2) Themes of this day were:
 - Sea level and Ocean heat observations from space.
 - Causes of sea level changes.
 - How satellite altimeter data sets are processed and apply geophysical and atmospheric corrections.
 - SAR altimetry using Sentinel-3 data.
 - Computing sea surface height anomalies using satellite altimetry (GOCE satellite data).
 - Ocean currents from altimetry data and also sensor data for Sea Surface Temperature, Salinity, Ocean Color, surface roughness
 - Lagrangian displacements
 - Ekman Currents and Lagrangian advections
- 3) **AUV drone demonstration** with Joao Sousa's lab (FEUP). We travelled down to the the port by bus and were divided into two groups. **Paolo Dias** and **Joao Pereira** presented about NEPTUS and real-time screen-monitoring from the AUVs. I asked about communications (Iridium), ranges of operation and sampling for biological matter.
- 4) After the demonstration, talked further with **Jose da Silva** regarding our project. Indeed, more interested in radar applications and SAR. We discussed the viability of doing SAR imagery through SmallSats (which is difficult but possible). Some are being developed already. I will send him documentation about our work, he was interested to see our engagement in a HSI mission.
- 5) Ended the day with common dinner with the students and later bar with a smaller group (again).

Lectures (please see NTNU SmallSat Google Drive)

- Lecture 4 "Sea level and ocean heat content from space".
- Lecture 5 "Measuring ocean surface currents from space".

Interactive lectures (please see NTNU SmallSat Google Drive)

- Interactive Lecture 4 "What can an ocean altimeter do for me".
- Interactive Lecture 5 "Investigating sea level and ocean heat content using satellite altimeters".
- Interactive Lecture 6 "Using satellite data to investigate ocean surface currents".
- Interactive Lecture 7 "Using satellite data to investigate ocean surface currents and transport".

Software used

- Broadview Radar Altimetry (BRAT - <http://www.altimetry.info/toolbox/>)
- Ocean Virtual Lab (OVL) which is open-source (<https://ovl.oceandatalab.com/>)
- SeaScope
- IPhyton notebook

WEDNESDAY 13TH SEPTEMBER - DAY 3

Highlights

Interactive lectures on ocean currents, winds and waves and salinity from surface; This was mainly **Jose da Silva's** day; Group work; **Bertrand Chapron from Ifremer** interested in our SmallSat.

Summary

- 1) Lectures and interactive lectures (see below).
- 2) Themes of this day were:
 - Surface wave interactions with currents, and how these can manifest in a SAR and/or an optical high-resolution image. Bragg and non-Bragg scattering.
 - Internal Solitary Wave (ISW) radar imaging.
 - Using Sentinel-1 C-band SAR wave mode and Sentinel-2 MSI data
 - Prediction of wave spatio-temporal evolution by using longer wavelength measurements (Sentinel-1 wave mode, Sentinel-2, Sentinel-3 SRAL, Jason2 and AltiKa).
 - Physics of internal waves and how to measure in-situ.
 - Bathymetry.
- 3) Group work started. Topics that we came up with were:
 - a) How do we exploit satellite data for monitoring objects in the ocean (e.g. fish, ships, plastics, oil spill)?;
 - b) How do we use remote sensing to monitoring changes in coastal ecosystems (e.g from hurricanes, slicks, outflows)?;
 - c) Identifying long-term variability of major ocean features (e.g. Western boundary currents, gyres) in remote sensing data;
 - d) Can EO support energy extraction from the ocean (e.g. from wind, tides, waves)?; and finally
 - e) How do we use data from the sentinels to accelerate scientific discoveries of the ocean?.
- 4) I ended up in the first group with more detailed topic: "Monitoring and modeling marine plastics using EO data". Brainstorming and research planning. Deliverables upon end of course was a research proposal (1 page), extending to 4 pages if viable and a presentation on Friday. I took "lead" in the project management and technical aspects of the proposal: risk assessment and mitigation; cost analysis; timeline; and plan for in-situ measurements for validation of EO data". Let me know if you want to know more about this proposal, but *not very relevant to our HSI mission apart from monitoring dynamics of habitats and chlorophyll due to plastics*.
- 5) Talked with **Bertrand Chapron from Ifremer, France**, and he was very interested in our HSI SmallSat project.
- 6) After 20:00 social activities.

Lectures (please see NTNU SmallSat Google Drive)

- Lecture 6 "Wind waves and wave current interaction from space".
- Lecture 7 "How to measure ocean waves from space".
- Lecture 7.5(11) "How to measure ocean waves from space: Internal waves from space".

Interactive lectures (please see NTNU SmallSat Google Drive)

- Interactive Lecture 9 "How to measure ocean waves from space".
- Interactive Lecture 10 "How to measure ocean waves from space: How do ocean waves impact ocean circulation?".

Software used

- Broadview Radar Altimetry (BRAT - <http://www.altimetry.info/toolbox/>)
- Ocean Virtual Lab (OVL) which is open-source (<https://ovl.oceandatalab.com/>)
- SeaScope
- IPython notebook

THURSDAY 14TH SEPTEMBER - DAY 4

Highlights

Interactive lectures on ocean surface salinity and marine inorganic carbon; trajectory for particles with ocean movement constraints (currents, SSH, SST and waves); Fluid flux modeling; **Johnny Johannessen, NERS, Norway** interested in our SmallSat; Group work.

- 1) Lectures and interactive lectures (see below).
- 2) Themes of this day were:
 - Sea surface salinity; L-band microwave emissions from the sea surface and geophysical corrections.
 - ESA SMOS data sets using SNAP and syntool.
 - Intra-seasonal to inter-annual precipitation impacts as well as large-scale river runoff from the AmazonOrinoco and Congo rivers and its offshore advection. Effects on cyclone/hurricane formation.
 - Satellite sensors to observe the marine inorganic cycle. Using Sentinel-3 data.
 - Estimation of inorganic components using software and empirical algorithms.
- 3) Connected with **Johnny Johannessen, NERS, Norway**. Following up with him.
- 4) Group work continued. Working on the methodology for monitoring and modeling marine plastics (even though only less than 20 % is on the surface, rest in the depth). Prepared presentation slides.
- 5) After 20:00 social activities.

Lectures (please see NTNU SmallSat Google Drive)

- Lecture 6: "Measuring ocean surface salinity from space".
- Lecture 7: "Marine Inorganic Carbon".

Interactive lectures (please see NTNU SmallSat Google Drive)

- Interactive lecture 12: "Investigating sea surface salinity from space".
- Interactive Lecture 13: "Investigating sea surface salinity from space".
- Interactive Lecture 14: "Estimating CO2 Fluxes from space".
- Interactive Lecture 15: "Estimating Ocean Acidification from space".

Software used

- ESA OceanFlux Flux Engine (<http://www.oceanflux-ghg.org/News/FluxEngine-updated>)
- SNAP
- SeaScope
- IPhyton notebook

FRIDAY 15TH SEPTEMBER - DAY 5 END

Highlights

Interactive lectures on sea ice concentration and extent, sea ice thickness, sea ice drift and sea level; Observing ocean movement constraints (currents, SSH, SST and waves under sea ice); Group work and research proposal presentation.

- 1) Lectures and interactive lectures (see below).
- 2) Themes of this day were:
 - Satellite observations for monitoring of changes in the high latitude and Arctic Ocean.
 - Sea ice concentration and extent, sea ice thickness, sea ice drift and sea level (GRACE, ERS-1/2, Sentinel-1 SAR data).
 - Climate change variables (SST, sea ice concentration, currents/Gulf stream, gyres, waves).
- 3) Group work continued. Prepared presentation slides.
- 4) Presented. I presented about project management stuff and technical aspects on how to complete the satellite observations, in-situ sampling with AUVs and observations with UAVs, extensions to what is possible. Presentation was well received. Still don't know who got the funding..
- 5) Wrapping up and thanks from FCUP and ESA.
- 6) After 17:00 social activities and sightseeing.

Lectures (please see NTNU SmallSat Google Drive)

- Lecture 8: "Polar oceans and Climate change from space" by J. Johannessen (NERS).

Interactive lectures (please see NTNU SmallSat Google Drive)

- Interactive lecture 16: "Understanding the polar oceans from space".
- Interactive Lecture 17: "Climate impact and the polar oceans".

Software used

- OVL
- Polar Thematic Exploitation Platform (TEP - <https://portal.polar-tep.eo.esa.int/>)
- SNAP
- SeaScope

COMPLETE LIST OF CONNECTIONS MADE

- Joao Sousa, FEUP, Porto
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- Jose C.B. da Silva, FCUP
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- Joao Pereira, FEUP
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- Joao Galante, FEUP
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- Renato Mendes, FCUP
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- Antoine Ndende Ba, University of Rennes, FR
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- Sam E. Hunt, National Physical Laboratory, UK
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- Johnny Johannessen, NERS, NO
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- Bertrand Chapron, Ifremer, FR
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- Dr. Craig Donlon, ESA (ESTEC)
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FOLLOW-UP ACTIONS

- 1) Coordinate with **Joao B. Sousa at FEUP, University of Porto** about collaboration on the following topics:
 - Send him documentation and material on current concept and mission design.
 - Extend discussions and agreements for using testing facilities for our HSI on drones. This would entail field testing in at the port of Porto, the Azores and Madeira.
 - Follow up on guidance/aid/example setting for their first *systems engineering* course at FEUP for undergraduate students in the week of 18th September. A good project for them would be how to design a HSI or Ground Station.
 - In case of a NTNU SmallSat flight, we talked about potential usage of ground station at University of Porto. They might build a ground station accommodating UHF/VHF or even S-band. If we want a low-latitude first flight, this might be a solution when observing a target area in e.g. the Azores.
 - Understand better about LSTS Toolchain; look into implementation for SmallSat mission operations.
- 2) Send documents/material on mission design and concept to **Jose C.B. da Silva at FCUP, University of Porto** and **Renato Mendes**. They are more inclined to radar applications (SAR, altimetry) for observing waves and geological events. But they are interested in our HSI SmallSat mission.
- 3) Send documents/material on mission design and concept to **Bertrand Chapron, IFREMER, France**. He is interested in our HSI SmallSat mission and the engineering aspect of coordinated observations (with in-situ validation of s/c observations).
- 4) Talk further with **Antoine Ba, University of Rennes, France**. He did his PhD in LIDAR and HSI for oceanography (incl. extensive work on atmospheric corrections). He knows about some tools we may use (Modtran, ATCOR, GLIMPS).
- 5) Send documents/material on mission design and concept to **Johnny A. Johannessen, NERS, Norway**. He is interested in our HSI SmallSat mission and how spectral domain may aid sea ice monitoring (climate change variables).
- 6) Finally, do a survey of the softwares and tools learned in the course and explore tools used for our application.