TU Delft

Theme 4 Project:
Test, Analysis and Simulation

Eddy formation in oceanic current systems from satellite altimetry and thermal images

Sentinel-6 Jason/CS. Credits: ESA/JPL/EUMETSAT/CNES

	name	contact	date
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1. The 4th Thematic Project

1.1. The scope and objectives

The thematic projects in the Aerospace Engineering Bachelor Program aim to provide learning experiences that will enable you to better integrate the theoretical content of the courses in a practical, active setting. The projects are mandatory elements of the program. Each semester contains one thematic project.
The theme of the 4th semester is "Test, analysis, and simulation". The courses in this semester, in general, have this theme in common. This theme also is the focus in this 4th semester AE2224-I project.

1.2. Activities within the project

The project will run in the second semester of the second year. Table 1 gives an overview of the activities during the project.

The deadlines within the project are:

<u>10 March 2023, 17:30</u>	Hand in literature review for scientific reporting. You will be provided with the relevant instructions in the introductory lecture in week 3.1. The report will not be directly graded.
<u>10 March 2023, 17:30</u>	Every student needs to hand in his individual introduction section. Feedback will be provided by your tutor.
<u>10 March 2023, 17:30</u>	Hand in research plan to tutor. This research plan should contain the first research steps (type of activity and distribution of tasks) you intend to take. It will help you to start and better define the research. In addition, it allows your tutor to give to-the-point feedback. This report will not be directly graded.
<u>31 March 2023, 17:30</u>	Submit self-reflection report to the project supervisor. This self-reflection should not exceed 1 A4 and should reflect on your own contribution to the project: - How did it go so far? - What are your insights on your own functioning within a group? - What have you identified as your strengths? - What weaknesses need to be improved upon? How do you intend to ensure these improvements?
<u>28 April 2023, 17:30</u>	Submit introduction and methods section for scientific reporting for teacher feedback.
<u>17 May 2023, 17:30</u>	Submit draft of scientific report for the peer review process (please note this is on a Wednesday)

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26 May 2023, 17:30	Submit peer review
16 June 2023, 17:30	Submit final version of scientific report to Brightspace, tutor and scientific reporting teacher

1.3. Grading

You will be graded at the end of the project based on the following items:

1. The scientific report. A **group grade** will be given based on the technical quality of the report. Each group member should indicate what part of the report he/she has produced. This will be used for grading.
2. Your attitude during the project. It is based on regular meetings with your tutor and your self-reflection and is an **individual grade**.
3. The project ends with an oral exam. During this exam the tutor, together with one of the project coordinators or teaching assistants, will test your understanding with regards to the research, resulting in an **individual grade**.
4. You all will be asked to review the report of another group individually. The quality of the review will be accounted for as an **individual grade**. This grade is provided by the tutor of the group whose report is reviewed.

Partial grades will be rounded to 1 decimal and the final grade will be rounded to the nearest halve grade. The tutor grade holds for 4 ECTS and 1 additional ECTS is given by the Scientific Reporting tutor for the quality of the report.

In order to pass the project, the following needs to be fulfilled:

1. The whole project has been completed and all compensatory assignments have been completed successfully and,
2. No more than one grade is lower than 6.0 and all grades are 5.0 or higher,
3. All rules regarding absence are met.

If any of the above conditions are not met, a final grade of 1.0 is awarded for the project. If you fail the project you have to reregister to redo the project the following academic year.

Table 1. The project activities.

When	Activity
Week 3.1	- Introductory lecture - Kick-off: meeting with the tutor
Week 3.2	- Information literacy 2 course - Start literature survey
Week 3.3	- **Scientific reporting coaching session 1 (for half the cohort)** - Literature survey
Week 3.4	- **Scientific reporting coaching session 1 (for the other half the cohort)** - Finalize literature survey - Write research plan

	- Start with data analysis - Submit literature review (10/3/2023) - Submit research plan to tutor (10/3/2023) - Submit Individual Introduction (10/3/2023)
Week 3.5	- Continue data analysis
Week 3.6	- Continue data analysis **- Scientific reporting coaching session 2 (for half the cohort)**
Week 3.7	**- Scientific reporting coaching session 2 (for the other half the cohort)** - Continue data analysis - Work on scientific report - Submit the self-reflection report (31/3/2023)
When	**Activity**
Week 4.1	- Continue data analysis - Work on scientific report
Week 4.2	**- Scientific writing coaching session 3 (for half the cohort)** - Continue data analysis - Work on scientific report
Week 4.3	**- Scientific writing coaching session 3 (for the other half the cohort)** - Continue data analysis - Work on scientific report
Week 4.4	- Continue data analysis - Work on scientific report - Draw conclusions - Submit draft of scientific report (17/5/2023), please note the deadline is on a Wednesday! - Submit peer review report (26/5/2023)
Week 4.5	**- Scientific writing coaching session 4 (<u>for all students</u>)** - Peer review of scientific reports
Week 4.6	- Register for a group session with your scientific writing teacher to receive feedback and for questions regarding the implementation of the peer review comments (the schedule for these sessions will be provided at the Scientific reporting coaching session 3). - Implementation of the comments from the peer review and finalize data analysis - Work on scientific report
Week 4.7	- Register for a group session with your scientific writing teacher to receive feedback and for questions regarding the implementation of the peer review comments (the schedule for these sessions will be provided at the Scientific reporting coaching session 3). - Implementation of the comments from the peer review and finalize data analysis - Work on scientific report
Week 4.8	- Deliver final report (16/6/2023)
Week 4.9 - 4.10	- Oral exam - Grading

1.4. Required presence and absence rules

Currently, the project is scheduled to be on campus. If the circumstances will require it the project might be carried out online using MS Teams. For each student group the project sessions will be scheduled, and a project space assigned (in case on campus education is possible). Within each group a member needs to be assigned who is responsible for recording the presence.

Presence during the project is compulsory and will be checked (both online and on-campus). The following rules hold:

1. The student must attend all scheduled project sessions.
2. The student must attend the first week of the project. Not being present in the first week of the project results in exclusion from participating in the project in that academic year.
3. Attendance is mandatory during the scheduled project session hours.
4. Project session starts either at 08:45 or 13:45, the project ends at either 12:30 or 17:30. Missing time by either being late or leaving at any time before the project end time is registered as missed sessions.
5. Students should be working on the project between the scheduled session start and end time. If a student is not working on the project during the project session it is registered as a missed sessions.
6. A missed session must be compensated by fulfilling a replacement assignment. The replacement assignment will be provided by the responsible lecturer to the student.
7. No opportunities are offered outside the duration of the project for making up a missed sessions.
8. Students are allowed to miss a maximum of 2 project sessions per period (half semester) due to illness, family circumstances or relevant extenuating circumstances. Reason for absence should be reported to the course responsible and TA's as soon as possible but at least before the project session starts.
9. If a project has a supporting course the student is only allowed to be absent for one session of this course. This session is not counted as a missed project session as mentioned under 8.
10. The student cannot obtain a passing grade for the project if the number of session as stated in either 8 and/or 9 are exceeded.
11. Students who are of the opinion that there are relevant extenuating circumstances can turn to the academic counsellors for guidance.

In case a group member is absent, he/she must plan in cooperation with his/her group on how to make up for the absence. The result must be communicated to the supervisor and its realization is based upon the supervisor's approval. Absence at a scientific reporting session needs to be reported to the scientific reporting teacher. A compensatory assignment will be provided. The student is responsible for fulfilling the compensatory assignment, at a time or within a time limit set by the responsible lecturer (this also applies to supporting courses). The quality of the compensatory assignment is assessed by the responsible lecturer. Not finishing the assignment within the allocated time and/or with sufficient quality, results in failing the project.

1.5. Peer evaluation and logbook

During the project there will be 2 occasions when there will be a peer evaluation of your group members. This evaluation is used to monitor the contribution of all group members to the project and to give feedback on their performance. The peer evaluations are scheduled roughly for week 3.7 and 4.7. Please note that these evaluations are not directly used for grading.

In addition, every student should maintain a logbook. At the end of each week this logbook should be updated and uploaded to Brightspace such that the TAs can review it. The logbook should contain the work that was carried out in the preceding week and the activities that will be done in the coming week. There can be a single logbook for each group, however the students are responsible for their individual entries.

2. The Assignment

Since 1985 there is high quality sea level anomaly data acquired by several satellite altimeter observing systems. A satellite altimeter is a microwave radar system, it is a downward looking instrument that illuminates a footprint of about 10 km in diameter beneath the satellite. The instrument returns so-called radar waveforms from which we can obtain an average sea level height [m], a significant wave height [m] and a radar signal backscatter value [dB]. Sea level anomaly data is normally measured along repeating ground tracks of satellites such as TOPEX/Poseidon, the JASON series altimeters and currently the Sentinel-6A altimeter. The ground track for some of the last three altimeters is the same so that an easy comparison can be made in time over the same geographic location; it takes approximately 10 days to fly a full ground track. For the T/P mission the 10 daily period is called a cycle and it consists of 127 orbital revolutions. A separate class of satellite altimeters fly in higher inclination orbits, often sun-synchronous orbits near 780 km above the Earth's surface. In this case the ocean surface is mapped in for instance a month, but not necessarily these missions fly in a repeating ground track. Typical examples are ERS-1 and ERS-2, CryoSat-2, SARAL, Sentinel 3B and others.

For this assignment the group is asked to work with the radar altimeter database system (RADS) developed and maintained by the Delft University of Technology. During the translation of raw instrument data to sea level anomalies a lot of known periodic and short-term systematic variations such as tides, altimeter instrument effects, electromagnetic bias of the altimeter and orbit errors are significantly reduced. The RADS database offers the possibility to return level-2 data for all satellite altimeters that have flown since 1985. The end product that we obtain from the radar measurements is what we call a sea level anomaly, a difference between the instantaneous sea level measured by the altimeter radar and a long term mean sea level.

Satellite altimetry yields a unique insight into the behavior of the oceans which store and transport heat. Height change as measured by the altimeter (when we apply corrections for tides and wind effects etc) is for a significant part heat change, and for this reason sea level anomaly data is an important climate variable because of the heat interaction between the atmosphere and the oceans, but also the result of ice sheet and glacier mass exchange and the oceans. The oceans have another remarkable feature which is that turbulence is demonstrated at the surface in so called western boundary regions. You can see this in the sea surface temperature maps which are collected from a wide variety of thermal imaging systems on satellites. Eddies (rings) are formed in the western boundary regions and they can start a life of their own wandering away from the frontal region. This is what can be seen in the Gulfstream but also in other major oceanic systems such as the Agulhas region and the Kuroshio region, the East Australia current, and the Brazil current system. Thermal images are generated on a daily basis and they can be accessed from the PODAAC website at JPL as the GHRSST level 4 MUR product. These thermal images clearly show the eddies in western boundary regions.

Task

The project assignment is to demonstrate the relation between sea level anomalies as recorded in the altimeter database RADS and the sea surface temperatures in the GHRSST level 4 MUR product. With this data you select a characteristic western boundary region such as the Gulfstream area. We ask you to identify the front of the Gulfstream and to show that it is meandering, try to do this with a sufficiently long dataset (that is for instance a year in length). Where are the eddies formed as you see them in the GHRSST dataset and in which direction do they dwell off into the Atlantic? Can you still follow them with the altimeter data? With the altimeter dataset we ask you to show the height profiles along the altimeter tracks, you will need several altimeter tracks to recognize an eddy field and you will see that the altimeter is better in sampling the sea surface along the ground track of the satellite, but, that some effort is required to form a complete image of the eddy field with the radar data. The research question for this project is to demonstrate the correspondence and the differences between both datasets. A scientific objective is to quantify the heat exchange in the system.

3. Project tutor

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4. Relevant courses

The following courses are relevant for this thematic project:

- AE1205 Programming and scientific computing in Python
- WI1403LR Linear Algebra
- AE1110-II Introduction to aerospace engineering II
- WI2180LR-II Probability and Statistics
- AE2223-II Experimental Research & Data Analysis

References/reading material

1. Coastal Altimetry, editors: Stefano Vignudelli, Andrey G. Kostianoy, Paolo Cipollini, Jérôme Benveniste, https://doi.org/10.1007/978-3-642-12796-0 (you can download the PDF of this book as a TU Delft student)
2. Satellite Altimetry and Earth Sciences: A Handbook of Techniques and Applications, Lee-Lueng Fu, Anny Cazenave, Academic Press 2001, *Volume 69 International geophysics series*, ISSN 0074-6142
3. TOPEX/Poseidon Mission overview, L.L. Fu et al, (1994) JGR Oceans Vol 99, C12, https://doi.org/10.1029/94JC01761
4. Principal Component Analysis in Meteorology and Oceanography, R.W. Preisendorfer, (1988) Development in Atmospheric Sciences 17, Elsevier, ISBN 0-444-43014-8
5. MATLAB primer, Mathworks, latest edition is for instance here: http://jeti.uni-freiburg.de/vorles_stat_num/getstart.pdf
6. Sea Level Change (2013) Assessment report AR5 Chapter 13 of the IPCC, https://www.ipcc.ch/report/ar5/wg1/sea-level-change/
7. Introduction to Physical Oceanography (2020), R.H. Stewart, Texas A&M University, https://open.umn.edu/opentextbooks/textbooks/20
8. Weisstein, Eric W. "Least Squares Fitting--Polynomial." From *MathWorld*--A Wolfram Web Resource. https://mathworld.wolfram.com/LeastSquaresFittingPolynomial.html

Dataset that are available for this project

1. Radar Altimeter Database System, RADS, http://rads.tudelft.nl/rads/rads.shtml

2. Group for high resolution sea surface temperatures (GHRSST) https://podaac.jpl.nasa.gov/dataset/MUR-JPL-L4-GLOB-v4.1