ISME Scholar Program Fund report

Additional funding support for 2 Erasmus+ traineeships

Meteorological Institute of Norway 04/03/2024-22/03/2024
Cardiff University 24/06/2024-05/07/2024

Modelling deep sea hydrocarbon spills in the Eastern Mediterranean Sea: Evolution and fate of deep-sea hydrocarbon plumes and their biodegradation in the marine environment

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Overview of the activity

The primary objective of this research was to simulate and study the dynamics of deep-sea hydrocarbon spills with two very advanced oil spill models, OpenDrift (developed by MET Norway) and OSCAR (developed by SINTEF), specifically focusing on the biodegradation of deep-sea hydrocarbon plumes.

During the first Erasmus+ traineeship, conducted at the Meteorological Institute of Norway (MET Norway) in Bergen (04/03/2024-22/03/2024), I ran simple scenarios of a deep-sea oil release using OpenDrift. Focus was given on the formation and drift patterns of hydrocarbon plumes at depth (~1000 m depth) and how biodegradation contributes and alters the final fate of the oil.
OpenDrift, as most oil spill modelling tools, uses a simple first order kinetic model for biodegradation based on Adcroft et al. 2010[1], where the decay timescale, R^{-1}, is temperature-dependent: $R^{-1} = 12 \text{ days} \times 3^{-(T-20^oC)/10^oC}$ (1).
In our previous research, we had acquired representative data about crude oil biodegradation rates under high pressure conditions, using an experimentation system that retains the high-pressure conditions under all stages, from the sampling of the microorganisms from the deep-sea to experimentation in the lab (Antoniou E., Fragkou E. et al., 2022)[2]. Hence, I wanted to use these findings in a deep-sea hydrocarbon spill scenario. During my visit, Knut-Frode Dagestad created and implemented another function in OpenOil code to accommodate biodegradation rates and half-lives that are user defined. This way, I managed to compare biodegradation rates reported in the literature with our findings. Data showed that temperature dependent biodegradation model can lead to misleading and unrepresentative results. At the same time, biodegradation rates obtained by emulating the conditions of the spill as accurately as possible, showed better performance than biodegradation rates obtained from other published studies, showcasing the importance of proper experimentation.

During the second Erasmus+ traineeship at Cardiff University in June (24/06/2024-05/07/2024) I ran subsea hydrocarbon spill scenarios using the OSCAR (Oil Spill Contingency and Response) model developed by SINTEF. SINTEF had provided an academic license of OSCAR to Prof. Tiago Alves at Cardiff University (School of Earth and Environmental Sciences), and during my 2-week visit I was able to run different scenarios of subsea hydrocarbon blowouts in the greater area of Eastern Mediterranean Sea and more specifically southwest of Crete, where there is an increased interest to exploit deep-sea hydrocarbons reserves.
The depth of release was set at 3000 m and parameters that were tested were: Type of

[1] https://doi.org/10.1029/2010GL044689
[2] https://doi.org/10.3390/en15134525

Hydrocarbons released, Subsea Dispersant Injection (SSDI) and Seasonal variations in Meteorological and Oceanographic Data (winds and currents). Focus was given on how much of the released hydrocarbons end up entrained in the water column, the formation of hydrocarbon plumes and how much of the total hydrocarbons released ends up biodegraded. OSCAR uses a pseudo first order kinetic for hydrocarbon degradation with a Q10 approach (Q10 values are the multipliers by which rates of enzymatic reactions increase at a 10 °C temperature rise). The OSCAR model assumes that microbial communities have the same temperature response and the same biodegradation capacity at a given (reference) temperature[3]. Since OSCAR uses a built-in library of biodegradation rates for different types of oil, I could not make a direct comparison with our data. However, oil spill modelling with OSCAR provided invaluable insights on the use of SSDI application.

A more in-depth analysis of the results obtained from the two traineeships is currently ongoing. When the results are finalized, the findings will be disseminated to the public. We can see that simplifications on biodegradation kinetics are important for Oil Spill Models to work robustly, however, for the hydrocarbon droplets that will remain subsea, it is important to examine their fate. Besides, most oil spill modelling simulation tools that take into consideration microbial degradation, only ever refer to primary biodegradation, the first stages where a compound is starting to degrade, and not the ultimate biodegradation, where the same component is completely mineralized to CO_2.

Deep sea oil spills pose a significant threat to marine ecosystems, and understanding the microbial dynamics involved in their remediation is pivotal for developing effective mitigation strategies. I am confident that the outcomes of this project will not only enrich the scientific community but also contribute to the broader goal of safeguarding our oceans from the adverse effects of oil spills.

ISME funding

The funding received from ISME was primarily used to cover travel and transport expenses for the two visits as well as accommodation costs, that could not be fully covered by the Erasmus+ program. This funding support allowed me to acquire the skills and knowledge required to conduct high impact research.

Promoting and highlighting ISME

During my visit at the Meteorological Institute of Norway, I had the opportunity to present my academic research regarding deep-sea microbial degradation of hydrocarbons, in esteemed organizations like NOFO-The Norwegian Clean Seas Association, the Norwegian Institute of Marine Research as well as the host organization of MET Norway. ISME's contribution for the visit and the ability to present this work was highlighted in each presentation. For those who had an interest or were involved in microbial research, I suggested to follow ISME's work and even attend the latest symposium of ISME19-19th International Symposium on Microbial Ecology.

After completing the second Erasmus+ traineeship at Cardiff University, I made a Linkedin post (https://www.linkedin.com/feed/update/urn:li:activity:7216032848963616769/) that received a lot of impressions, acknowledging ISME's funding support for both visits. I personally received the Scholar Fund that ISME provides for MSc and PhD students, as well as Postdoctoral fellows, to further develop their academic knowledge and skills at hosting Institutions. The support ISME shows to early career scientists is fundamental and I am very pleased that there are such initiatives.

[3] https://doi.org/10.1016/j.marenvres.2013.05.005

Figure 1: Opening and closing slides from different presentations during the first Erasmus+ traineeship in Bergen.