Blue-Cloud Hackathon Winners
Final Report

Please answer the following questions as best as you can

Team Name: ***The Particle Trackers***
Team Participants:

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Project Name: ***SeaClearly***
Submission date of this report: ***September 2022***

About your project

1. **About the team:** Describe your affiliation and/or research community and research domain? (max. 50 words)

We are a group of early career physical oceanographers working in the marine litter transport research domain. We are affiliated to 4 different institutions:

- Utrecht University, Netherlands
- University of Bern, Switzerland
- Imperial College London, UK
- Center for Ocean-Atmospheric Prediction Studies,Florida State University, USA

2. Project summary and milestones/tasks that have been completed (max. 300 words)

Summary:
SeaClearly is a tool that uses advanced computer simulations and tracking methods to identify the impact of marine plastic on aquaculture farms, as well as the impact of plastic pollution originating off aquaculture cages to the environment, specifically to marine protected areas (MPAs).

Project development:

- We implemented our solution via forward and backward tracking of virtual particles to and from the aquaculture cages, using an open-access particle-tracking framework, OceanParcels (https://oceanparcels.org/). This includes computer-modelled 2D surface flow data (CMEMS) and Mediterranean plastic concentrations (from Kaandorp *et al*. 2020,

Meijer *et al*. 2021, Jambeck *et al.* 2015). We currently run the simulations for a year to account for seasonal effects. When a particle makes contact with an aquaculture cage we record this as a potential consumption by marine species (or trapping by filter-feeders, like shellfish). We perform an advanced probability analysis (Bayesian) to provide the most likely origin (coastal area) of the particles that reach aquaculture farms. Finally, we repeat this entire process with the aquaculture farms as the origin of plastic pollution to indicate the impacts of the farms on the surrounding marine ecosystem.

- With this, we have reached the two main development milestones:
    1. SeaClearly tool can identify the likelihood and concentrations of plastic released from the Mediterranean coast reaching all aquaculture farms (registered in the Blue-Cloud database) in the Mediterranean Sea which helps identify the impact of plastic pollution (for example by plastic ingestion) on farm produce.
    2. Pathways of micro-plastic particles originating from the cages of the aquaculture farms in the Mediterranean Sea can be tracked by the SeaClearly tool to identify their most likely destination and prevent future contamination of the surrounding area which, for example, could include MPAs.

- An interactive website https://seaclearly.io/ that displays simulated microplastic pollution trajectories that interact with aquaculture farms in the Mediterranean is live at the moment. This website is a prototype tool under continuous development that provides information on the geographic location of aquaculture farms in the Mediterranean, together with dynamic visualisations of the movement of microplastic pollution affecting these farms. The tool uses the open-source lagrangian visualisation software ParticleViz. This allows for the further user accessibility-focused milestone:
    3. Anyone with access to the internet can use the SeaClearly tool, either on a desktop computer or a mobile phone, allowing curious consumers, aquaculture farmers, policy makers and other interested members of the public to have a quick look at how plastic pollution is affecting their local aquaculture farm or local marine area in general.

- Random locations in the Mediterranean can now be selected in the SeaClearly tool and plastic tracking software calculates the potential risk to and from this area. This allows for the stakeholder focused milestone:
    4. Policy and aquaculture stakeholders, and other curious individuals, are given full access to all the code and data that we currently have. A pollution risk assessment can be run, independent of whether an aquaculture farm is already present. These ‘blind’ locations can be used for ‘what-if’-scenarios and to explore potential locations for aquaculture farms or marine protected areas or any other marine activity and the SeaClearly tool provides detailed information about the dual risk of pollution to the aquaculture produce as well as the pollution from the farm to local and regional marine protected areas.

- The SeaClearly tool has been tested and developed such that it can also run on the Blue-Cloud virtual research lab. This leads to the last Blue-Cloud development and educational milestone:

5. More educated users and developers without access to computational resources in the means of a university or commercial license, can use and also co-develop our SeaClearly tool and can learn about and interact with it as an example of the data and applications available on the Blue-Cloud.

3. **Challenges**: Describe the particular scientific, technical, research or business challenges that you faced. Describe deviations from the initial project plans (max. 100 words)

As scientists, it was a business learning process for us to engage with (aquaculture) stakeholders and to make stakeholder engagement plans. The coaching sessions with IMEC were very helpful in this.

Initially, we planned to make an app alongside the website, however the technological challenges as well as the complications with hosting and future maintenance of an app were too big to solve in the time span of the hackathon project. The website, however, performs very well as a mobile phone web-application so the end goal of mobile device users easily accessing the tool is still reached.

Finally, it took a few months to start the project after winning the hackathon. We were full-time employed PhDs and postdocs, and taking time out of our current individual projects to work on this team project took a little bit of organisation. Also for most of us, working with a short paced, team delivery focused style rather than individual long term style was new, fun but also challenging at times.

The benefit of Blue-Cloud

4. **Blue-Cloud Relevant Outputs.** Summarise how your work is relevant in the context of Blue-Cloud e.g as a user how you leveraged Blue-Cloud outputs and results and the Open Science platform around 100 words)

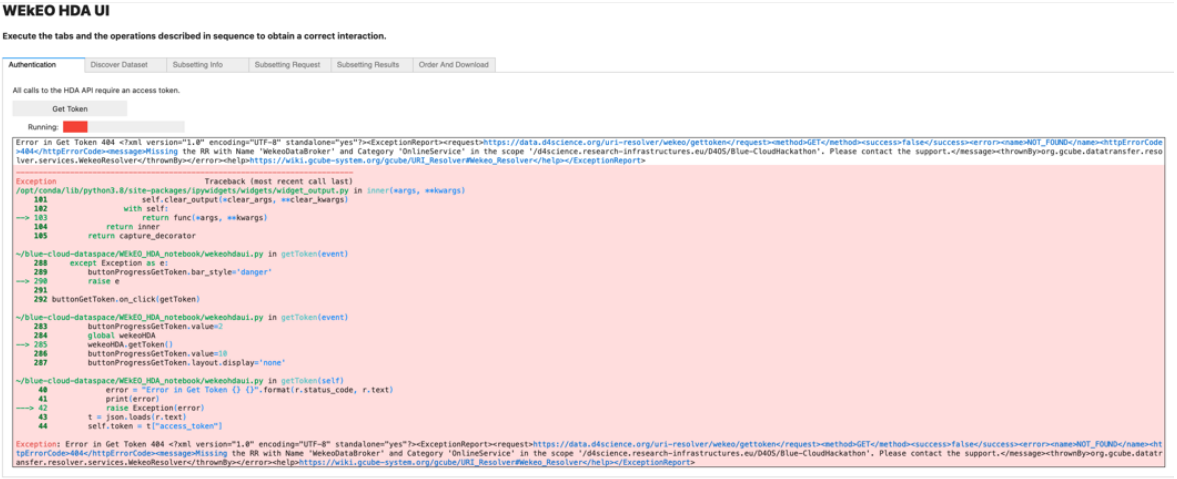
The code is on GitHub and anyone with access to the Blue-Cloud virtual lab space can clone the SeaClearly repository on the Blue-Cloud in the home folder (/home/jovyan) by use of a terminal on the jupyter hub. As input data we use CMEMS flow fields and locations of aquaculture farms, marine protected areas etc which are all available on the Blue-Cloud data platform. Postprocessing and ‘running’ the tool is done via a Jupyter Notebook which is available on the jupyter hub too. Some support from the Blue-Cloud technical team is needed to set up the virtual research environment (VRE) on the Blue-Cloud to work with our tool (see ‘feedback for the Blue-Cloud’ section for further details).

5. **User feedback**. Please provide your user feedback on the services provided by Blue-Cloud (around 100 words)

We used the Blue-Cloud virtual labs on the hackathon project page to run our software in order to make it accessible to co-developers and to all current and future Blue-Cloud users. We used all input data from the existing Blue-Cloud platform and where needed we asked for new or higher resolution versions of existing data to which the Blue-Cloud technical support team responded very positively.

There were some technical problems:

1. To change input data for the tool we had two options, of which one runs in to an error that we didn't have the time to solve: Open jupyter notebook - Go to directory
   cd ~/Blue-Cloud-dataspace/WEkEO_HDA_notebook/
   then run:
   %run -i ./wekeohdaui.py
   There is an error related to a token, see image:



Temporary solution to 1:
To circumvent this we needed to use a script to download CMEMS data that were already available from another source than the Blue-Cloud data. The script requires the motuclient package that is already available on the Blue-Cloud standard server. This download script can be found in our Git on the Sea_Clearly/data folder. This means the user has to find another resource to extract and store CMEMS data (openly accessible) than the Blue-Cloud which is not ideal.

2. Getting a virtual environment working on the Blue-Cloud in order to run our tool is not straightforward. The set-up of the environment usually only needs to be done once, especially for the Parcels software to run packages, it can all be installed using conda. However, the problem is that the virtual environment is reset after some amount of time. The solution below has ideally only to be done once, but these steps currently need to be repeated.

Solution to 2: To install a new environment, a docker image needs to be made. The docker file for the SeaClearly server is included in the Git at Sea_Clearly/docker/ folder. In this file, a base image is loaded (jupyter/datascience-notebook) which already contains a lot of standard datascience packages. In the remaining lines, additional packages are installed via conda/mamba. The dockerfile is then uploaded to the following git:

github.com/EGI-Federation/egi-notebooks-images/single-user-seaclearly/ using a pull request (PR). The Blue-Cloud support team then created the docker image/virtual research environment (VRE) out of this file on the Blue-Cloud server.

3. Packages to run the SeaClearly tool in parallel (multiprocess) are missing. If the image gets updated in the future, these can be added which will speed up the process a lot.

Solution to 3:
We currently install the missing package manually after the docker image is created.

6. **Benefits:** Please describe the main benefits obtained through the use of the Blue-Cloud resources and who benefits from it. (around 100 words)

The Blue-Cloud data and virtual lab platform allows us to share the tool with co-developers and with the public without the need for access to protected institutional data and/or computing resources. We found that although using our institutional computational resources resulted in a quick start-up and initial development, sharing it across institutions even within the core development team required different setup/packages/data structures for every server/system. This means there is a barrier of knowledge on how to set-up a virtual research environment and how to download and install data and packages which need to be re-invented and developed for every institutional server setup and user. By using the Blue-Cloud, it 'looks the same' for all users from all institutions and backgrounds which can be documented to help users with less computing skills to set-up and play around with the tool and the Blue-Cloud as a whole. Attracting more users of more variable backgrounds will, in the end, be beneficial for the development of the final product as well as for the Blue-Cloud and connected services itself.

7. **Tips & Tricks:** Did you consult any Blue-Cloud training resources or sessions? Do you have any tips & tricks for potential users of the Blue-Cloud resource you used? (max. 50 words) (optional)

We extensively interacted with the Blue-Cloud technical support team via email and they supported us in uploading requested data to Blue-Cloud and setting up the jupyter notebook on Blue-Cloud virtual labs.

8. **Limitations and future improvement**: What additional features would you like to see in the next version of the resource you used? (max. 50 words) (optional)

- At the moment there is an issue that only few of the Parcels output files are actually written. We think it has to do with an issue where multiple scripts are trying to write at the same time. This would be one of the first things to fix in the future. On the Jupyter Hub running on Lorenz (our server at Utrecht University) the issue can not be reproduced.

Outreach & Impact

9. **Outreach activities/events:** Did you participate in and or organise any outreach activities? Please provide information about the event, the participants and numbers and links. Are there resources produced that can be reused (no limits)

Digital Twin Ocean Forum
date: 20-21 May 2022, Paris, France
summary: Mercator Ocean International organised the European networking workshop (only 50 experts in Europe were invited to attend). Sea Clearly represented both a potential example for a digital twin as well as Delphine representing the voice of Early Career Ocean Professionals (ECOPs) that are an integral part of the UN Decade of Ocean Science for Sustainable Development goals. Following the statement from Emanuel Macron that a digital twin needs to be designed by 2023 in Brest in the One Ocean Summit in February 2022, the aim of this workshop was to start co-designing what a digital twin of the ocean should look like and who should be involved.
participants: ~50 in person, European scientists and policymakers.
resources: The summit's webpage can be found here:
https://www.mercator-ocean.eu/en/events/digital-ocean-forum/

EU Green Week 2022 partner event - Digital solutions for a sustainable blue economy
date: 1 June 2022, online event
summary: The EU Green Week is an annual event to debate European environmental policy with policymakers, leading environmentalists and stakeholders from Europe and beyond. This year's edition focused on the European Green Deal - the EU's sustainable and transformative growth strategy for a resource-efficient and climate-neutral Europe by 2050. Throughout the week, partner events took place, and the Blue-Cloud hosted one of them. The webinar organized introduced the Blue-Cloud services and three practical use cases which were the winners of the Hackathon held in February 2022. One of these applications was our project : Sea Clearly, and we were invited to present it. We showed the idea behind this tool and our implementation plan.
participants: ~30
resources:
https://blue-cloud.org/events/eu-green-week-digital-solutions-sustainable-blue-economy

International Digital Twins of the Ocean Summit (DITTO)
date: 4/5 May 2022, London, UK
summary: Building on the outcomes of the G7 presidency and led by the DITTO programme of the UK UN Decade of Ocean Science for Sustainable Development, a high level in-person DITTO summit was organised in London. The Sea Clearly team was invited for a key-note presentation about the experience and outcomes of the Blue-Cloud Hackathon as well as a seat in one of the panel discussions.
participants: ~150 in person + more via the live stream online, EU, UK, and German politicians, scientists, stakeholders from public and private sectors.

resources: The summit resulted in a whitepaper about DITTO development and governance which can be found here:
https://www.g7fsoi.org/wp-content/uploads/2022/05/DITTO-Programme-Whitepaper_1.pdf

European Commision: How to engage with the Mission "Restore our Ocean and Waters by 2030":
date: 13/14 June 2022, Marseille, France
summary: This event focused on the Horizon Europe Mission "Restore our Ocean and Waters by 2030" implementation and its planned actions to accelerate the transition to zero pollution in the Mediterranean Sea. The Sea Clearly team was represented with 2 speeches on the Torchlight event, and 2 more speeches during the evening network event.
participants: ~200 in person + more via an online live stream, High level politicians (amongst which EU commissioners, the mayor of Marseille, ministers of Education,etc) and representatives of research institutes and other stakeholders in the Mission. A particular focus was on youth representation and engagement with the mission.

Feature article in International Aquafeed and Fish Farming Technology magazine:
summary: published and printed monthly, we wrote a feature article about the Sea Clearly project. It can be found on page 38-40 of August 2022 edition: https://aquafeed.co.uk/magazine/

Use case on Copernicus marine services website:
summary: Copernicus marine services is a EU funded by oceanographers as a resource for their ocean model data. We used some of their services in our project and have a mention of our work on their website: https://marine.copernicus.eu/services/use-cases/sea-clearly-ocean-plastic-tool

Final outreach event:
date: 23 August 2022, online
summary: online interactive webinar (1hr) about the background of the Sea Clearly tool and how to install and use it.
participants: 80 participants, no registration needed so not entirely clear who the participants are but based on previous webinars hosted by the ocean plastic webinar platform (>500 subscribers) they include mainly early career scientists, plastic focused non-profit organizations and interested members of the public.
Resources: The full webinar can be viewed here:
https://www.youtube.com/watch?v=SR8aUDHdbWE

Events in the future:

FICCS: Foro Internacional de Ciencia, Comunicación y Desarrollo Sostenible
date: 21-24 September 2022 , Las Palmas de Gran Canaria, Spain.
summary: The International Forum on Science, Communication and Sustainable Development focuses on science outreach and environmental awareness based on the Sustainable Development Goals. The Forum is dealing with problems linked to the ocean, island communities, local fauna, local economic development, climate change, and the role that citizen science and science outreach plays in solving these problems. The Sea Clearly team will be part of a panel discussion about tools to assess the impact of plastic emitted from aquaculture farms.
resources:
https://www.citizensbyplanet.org/ficcs-lugar

Annual Meeting of the Mexican Geophysical Union (RAUGM): SeaClearly with ParticleViz
date: 1/5 November, Puerto Vallarta, Mexico.
summary: International conference presentation of the Sea Clearly tool and the Open Source software ParticleViz, used to generate the Sea Clearly dynamic tool.
participants: The RAUGM is a large international conference with thousands of participants and hundreds of talks in multiple fields of the Earth Sciences. In 2016, it had 833 presentations distributed in 19 regular sessions and 22 special sessions. The sessions were presented in six simultaneous rooms and it had a large area for posters and an exposition with participants from the private and public sector. In a single presentation the average number of participants were around 100.
Conference website: https://raugm.org.mx

Final Blue-Cloud conference:
date: 6/7 December, Brussels, Belgium.

Online presence count:

- **272 views** of the Sea Clearly pitch https://www.youtube.com/watch?v=qJiSiDFbdhE
- The twitter account of our research group (https://twitter.com/UFollowtheOcean with **6000 followers**) was used to promote the webinar and other outreach events.
- We tweeted about Sea Clearly regularly receiving on average over **2000 impressions and over 100 interactions** per tweet.
- website: on http://seaclearly.io/ (previously hosted on the COAPS domain) anyone interested with a web browser on computer or mobile device can play around with our tool.

10. **Impact:** What is the impact of your project (activities/outcomes, etc.) for your team and institute? What is the impact for scientists, citizen scientists, government bodies and industries, and the public? (around 200 words)

Through the hackathon and the development of our idea these last 6 months, our team has been invited to numerous events and workshops (see point 9 above). Through these outreach activities, we have seen the interest and need for the development of a tool like SeaClearly. The feedback from stakeholders and professionals across many disciplines has been that multidisciplinary innovative (and user-friendly tech-based) solutions to anthropogenically caused threats on the environment are a promising way forward. Furthermore, as a team of early career ocean professionals, Sea Clearly has built our self-confidence that regardless of our career stage, we can come up with creative, impactful ideas and we are considered as experts in our field. Our institutes have also highly benefited from the exposure thanks to this project.

Sea Clearly is a tool that can be used by a number of end-users: businesses/industries (aquaculture farmers), local governments/authorities (managing marine protected areas), the general public (with an interest in safe fish and plastic pollution oceanic movement), and scientists (understanding the ocean currents and how things can be transported by

them). With a commercial version of Sea Clearly, safe and clean fish could be farmed by offshore aquaculture farms, and marine protected areas could remain free from plastic wear-and-tear from cages.