Modeling trajectories of Fish Aggregating Devices with satellite images: Use cases related to Fisheries

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SUMMARY

This note presents some work related to simulations of FAD trajectories using observations of Drifters and simulations with a model (Ichthyop) driven by satellite products for sea surface currents (OSCAR). We have different goals in mind: predicting the areas where FAD could drift, probability of damaging coral by stranding in reefs areas...

KEYWORDS: Fishing Aggregating Devices, scientific cloud, Drifting simulations, Ichthyop model, grid computing, online processing

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1. Introduction

The recent availability of data on Fish Aggregating Devices (FADs) used in tropical tuna purse seine fisheries has generated various research questions that are not all related to fisheries management. In a first step, GPS positions of buoys equipping the FADs provided by French fishing companies were analyzed to improve our understanding of FAD use and better estimate the overall fishing effort exerted on tuna populations [Maufroy et al., 2015, 2016]. FAD data were also used to evaluate the proportion of FADs that could end beach on some coastal ecosystems with vulnerable coral reefs [Maufroy et al., 2015]. More recently, some work has been initiated to compare trajectories of FADs with oceanographic drifters to determine if FADs are "good" drifters. To achieve such comparison, Ocean Surface Current Analyses Real-time satellite products (OSCAR) were used to compare the behaviour of both types of drifting objects, i.e. drifters and FADs [Imzilen et al., in prep]. Preliminary analysis seems to demonstrate a very similar behaviour of FADs and drifters in both the Indian and Atlantic Oceans. Here, we assume that drifters and FADs observations could equally be used to estimate the quality of Ichthyop model outputs (http://www.ichthyop.org/) by simulating trajectories of drifting objects deployed at the same location and date. We discuss our preliminary results dealing with the predictive quality of Lagrangian simulations along with the interest of running model simulations within a scientific cloud. We finally discuss the further steps of the work and mutual interest of collaboration between fishermen and scientists for further studies using FAD data.

2. Observed and simulated FADs trajectories: Use cases

We identified several use cases that could be addressed with the information gained from FAD data and Lagrangian trajectory modelling:

- Test the hypothesis that FADs drift like oceanographic drifters in near-surface currents by comparing FADs and drifters trajectories. We used two different approaches to address this topic: (i) direct comparisons of observed trajectories (Figure 1) and (ii) enrichment of FADs trajectories with environmental data (i.e. OSCAR) to compare FADs - OSCAR with Drifters - OSCAR [Imzilen et al., in prep],
- Assess the quality of OSCAR-driven Ichthyop simulations with observations of FADs and drifters (present study),
- Quantify the uncertainty associated with Lagrangian simulations using

different input data: (i) satellite images such as OSCAR and GECKO and (ii) ocean model outputs such as ROMS, Drakkar, MARS-3D, HYCOM, etc.

- Estimate the magnitude and spatio-temporal patterns of tag mixing in tuna populations from the mark-recapture data collected during the Indian Ocean Tuna Tagging Program (IOTTP). Preliminary analysis indicated that near-surface currents were good predictors of the date and position of recoveries for juveniles of tunas tagged along the coasts of Tanzania in 2006-2007, suggesting some passive movements during several months (Langley 2013),

- Quantify the extent of associative behaviour of pelagic species such as tropical tunas and sharks with floating objects by coupling observations of FAD drift with fish trajectories derived from pop-up satellite archival tags (ongoing work with C Lett and D Mouillot),

- Prevent beaching and coral reef damages by identifying risky areas for deployments of FADs. The approach requires first to have a good knowledge of the coral reef spatial extent and coverage in the Indian Ocean which appears to be scattered between countries and institutions,

- Reduce the loss of FADs that would be deployed in time-areas where they would likely drift quickly outside purse seine fishing grounds, e.g. the eastern part of the Indian Ocean,

- Predict the areas of occurrence of larvae and early-juveniles of tunas and time duration between egg hatching and recruitment in the purse seine fishery (at ∼30 cm) from the identification of spawning periods and areas.

3. Comparisons of FADs and drifters trajectories

3.1 Direct comparisons of observed FADs and drifters trajectories

Some basic indices have been tried to find similar FADs and Drifters trajectories (meaning close in terms of temporal and spatial distances). For example, we used a combination of spatial and temporal buffers to classify matching trajectories by using the sum of areas for intersecting polygons. Figure 1 shows the best matching we found so far. But we found plenty of additional couples which suggest that FADs trajectories could be compared with drifters ones. Of course, this method is opportunistic and it would be interesting to set up a collaboration between fishermen and oceanographers to deploy FADs together with drifters from fishing vessels.

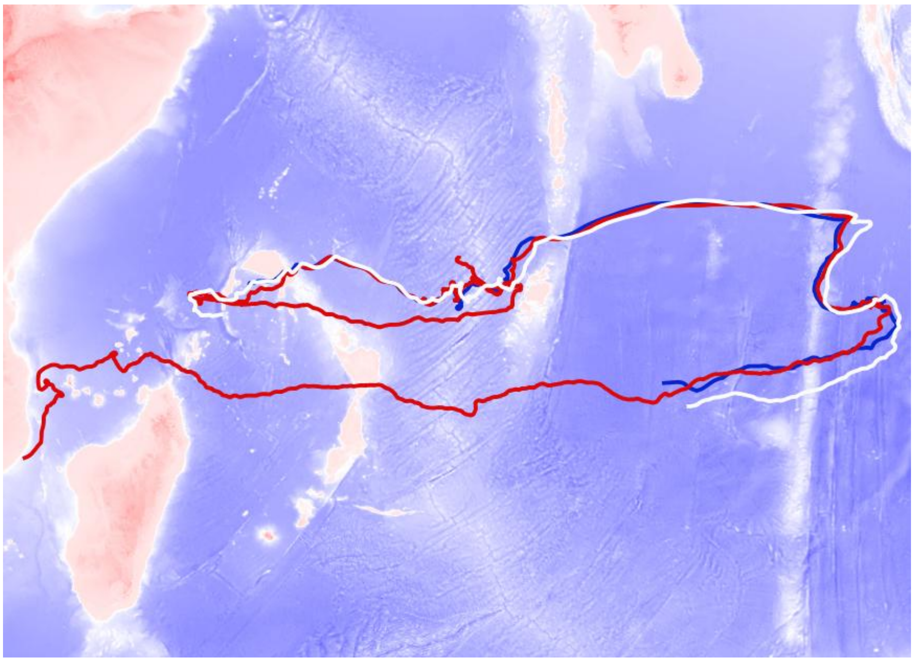


Figure 1: Trajectories of Drifters and FADs: in situ observations

3.2 Comparison of FADs and drifters in situ data with remote sensing products

Another work consists in confronting the results of FADs and drifters data when compared to OSCAR satellite products. In this case, each in situ data is compared the closest OSCAR data (in time and space). Figure 2 gives an example of result and shows that FADs and drifters are very similar.

A similar approach could be used with other products (remote sensing or model outputs). However, as FADs and Drifters data can be considered similar enough, we can use these two sources of data independently to assess the quality of Ichthyop simulations by using comparisons with observations.

For all these use cases, Ichthyop model can help. Most of the times the need consists in seeing if the simulations of Ichthyop driven by OSCAR data are worth to replicate observations.

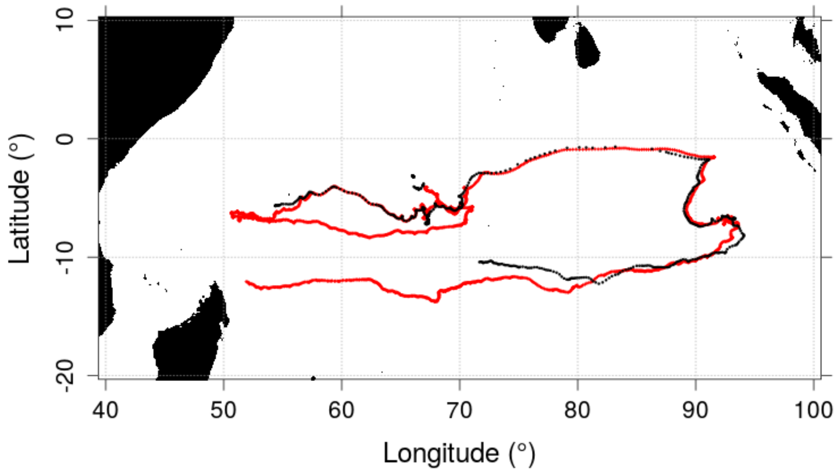


Figure 2: Trajectories of Drifters ans FADs

4. Comparisons of simulated and observed trajectories (FADs or Drifters)

In this section, we report our ongoing work to assess the quality of Ichthtyop simulations by comparing outputs of the model (driven by OSCAR products) with in situ observations (FADS or Drifters).

4.1 General approach

As shown in Figure 3, the quality of Ichthyop simulations can be more or less accurate, according to the locations and periods of FADs deployments.

4.2 Large-scale simulations

OSCAR data are available from 1992 until now. To cover the needs of all possible simulations for this period in the Indian Ocean, we need to run and analyze as many simulations as available trajectories of FADs or Drifters, which means:

- 10000 FADs trajectories (see Figure 4a),
- 10000 trajectories FADs trajectories (see Figure 4b).

The mean time execution for a simulation (for Drifters or FADs) when using Ichthyop and OSCAR data through OPenDAP protocol is around 5 minutes.

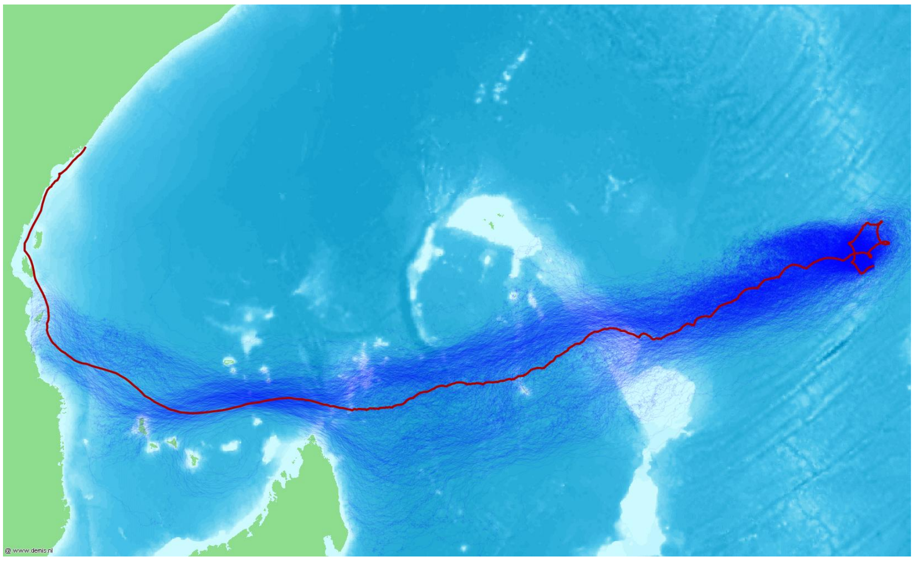
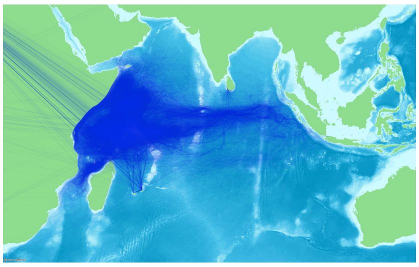
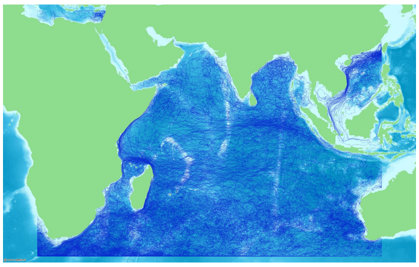


Figure 3: Example of simulation with Ichthyop: comparing observed trajectory with simulated ones



(a) FADs in Indian Ocean



(b) Drifters in Indian Ocean

Figure 4: FADs and drifters trajectories in Indian Ocean

At this scale, it becomes difficult to run so many simulations on a PC. We thus decided to execute simulations online within a scientific cloud to deal with the workflow described in 5

4.21 Web processing Services

The BlueBridge project and underlying IT infrastructure provided a set of useful services to access and parametrize such a workflow [Candela et al., 2015]. The Figure 6 illustrates how services can be managed in the cloud and accessible remotely from a local PC.

For example, it is now possible to run a simulation of Ichthyop remotely, from a Web browser or programmatically, by requesting the following WPS URL.

By iterating on such a Web Service, we can parallelize the execution of sim-

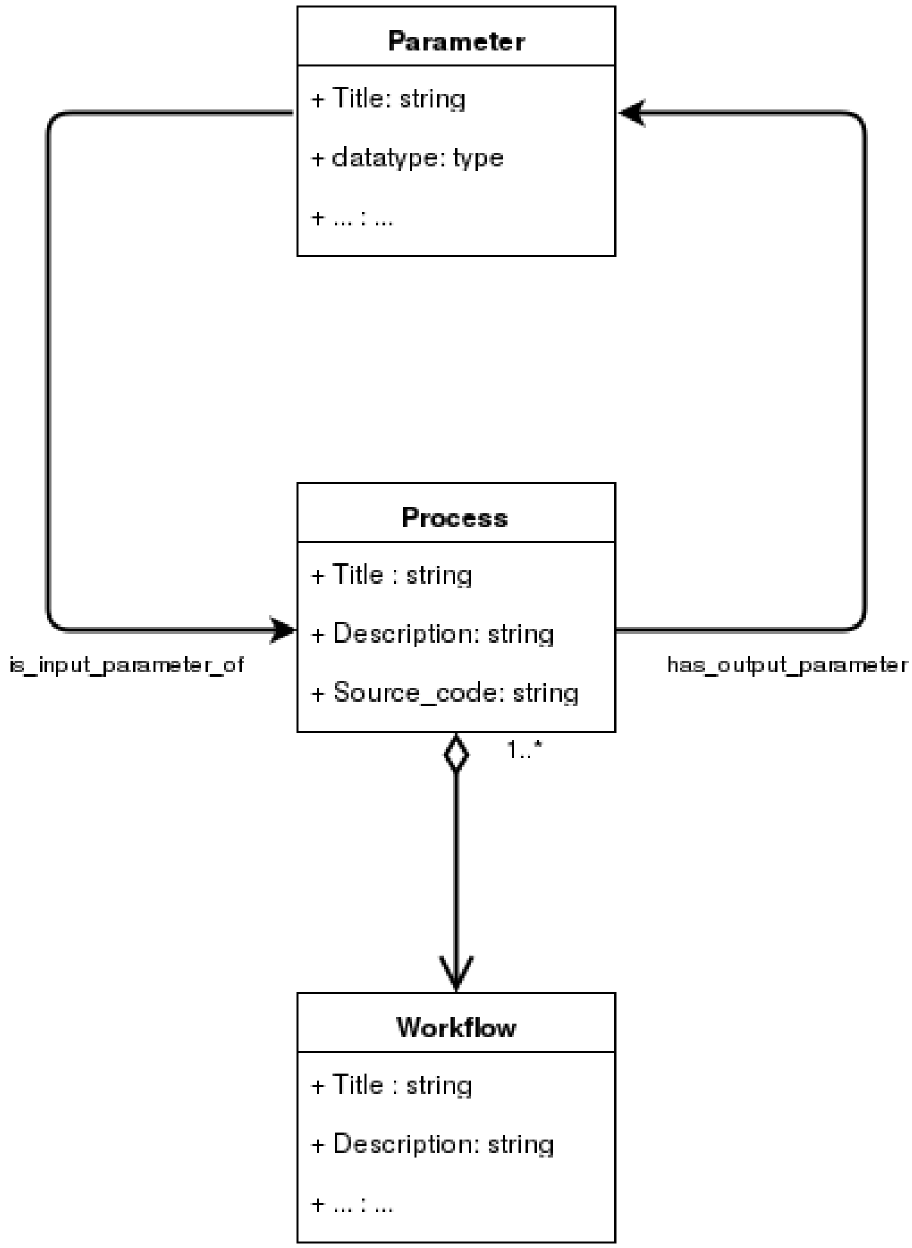


Figure 5: Workflow to run a lot of Ichthyop simulations

ulations on the infrastructure to improve the execution time. However, since model outputs are stored in this infrastructure, accessing these data becomes a key issue. Data formats and access protocols are crucial to address such issues.

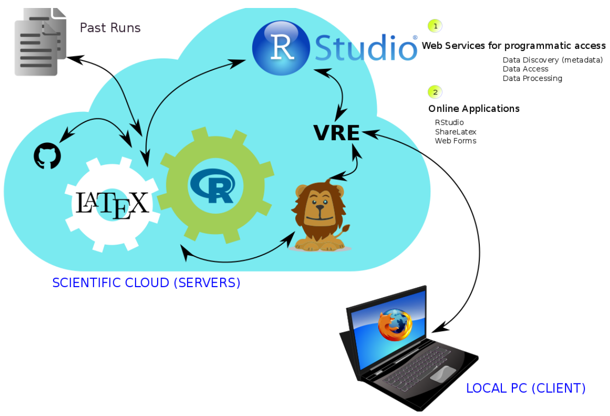


Figure 6: VRE: a collaborative Website to access services managed in a scientific cloud

4.22 Data structure and access protocols

The main question in this part of the work was how to facilitate the access to model outputs when simulating thousands of trajectories and generating as many output files. A set of 10000 simulations would give around 100GB of netCDF outputs (around 10MB per simulation). However, it was not an option for users to access each output file separately, and we needed to find a way to give access to all simulations through a single enpoint.

As Ichthyop model outputs are natively packaged within netCDF data format, a good option consisted in creating a NCML (virtual file) which gives access to all simulations though a single enpoint (OpenDAP URL). However to achieve this we needed to restructure the data structure of native netCDF files as they missed some important characteristics to be aggregated into a single and standardized NCML file.

In this section we propose to adopt a similar data structure to package both observed and simulated FADS trajectories. Indeed, FADs data and Ichthyop simulations outputs can be packaged by using the guidelines and good practices for ocean observatories datasets dealing with trajectories. We suggest to follow:

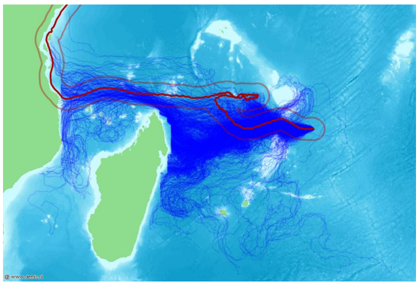
- the OGC standard for moving features,
- the CF Conventions and guidelines for trajectories data in order to package FADs data within netCDF files.

[Coro et al., 2015]
Examples of outputs.

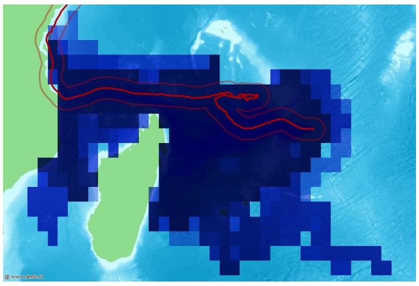
5. Outputs and Expected products

6. Outputs and Expected products

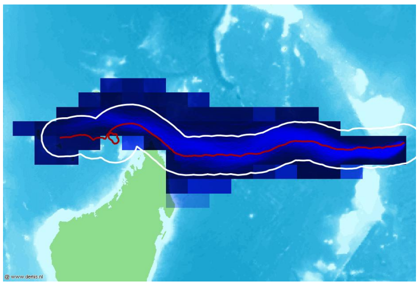
We plan to establish a map with deployments location and related quality of simulations (function of drifting time). To achieve this we needed to set up indices to estimate the quality of a simulation.



(a) Vector Indices to flag the quality of Ichthyop simulations



(b) Raster Indices to flag the quality of Ichthyop simulations



(c) Raster Raster Indices to flag the quality of Ichthyop simulations

Figure 7: Raster indices to flag the quality of Ichthyop simulations

7. Results and Discussion

The present article reports how FAD data, like drifters, can be used to validate Lagrangian model outputs and help to predict possible trajectories of FADs when deployed at a certain date and location. Depending on areas and periods, the quality of forecasts appears to be heterogeneous. Moreover, it is expected that type of current products used to drive the model will have an influence on the simulations, i.e. outputs from physical models such as ROMs or satellite products such as OSCAR or GECKO. So does the parametrization of the model (diffusion, number of trajectories simulated, etc.). The next steps would thus consist in comparing model outputs depending on the parametrization and kind of input data used. However such a work can be achieved without dealing with large scale analysis issues. Indeed, the machine resources required for such data analysis go beyond PC resources as time execution require days and TB of inputs and output data only for simulations, and extra time is required to analyse simulations outputs. This is the reason why a basis for this work consisted in enabling such processes to be executed on a scientific cloud by complying with standards for both data access and process execution.

Acknowledgements

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References

L. Candela, D. Castelli, G. Coro, L. Lelii, F. Mangiacrapa, V. Marioli, and P. Pagano. An infrastructure-oriented approach for supporting biodiversity research. Ecological Informatics, 26, Part 2:162 – 172, 2015. ISSN 1574-9541. doi: http://dx.doi.org/10.1016/j.ecoinf.2014.07.006. URL http://www.sciencedirect.com/science/article/pii/S1574954114001022. Information and Decision Support Systems for Agriculture and Environment.

G. Coro, L. Candela, P. Pagano, A. Italiano, and L. Liccardo. Parallelizing the execution of native data mining algorithms for computational biology. Concurrency and Computation: Practice and Experience, 27(17):4630–4644, 2015. ISSN 1532-0634. doi: 10.1002/cpe.3435. URL http://dx.doi.org/10.1002/cpe.3435.

T. Imzilen, H. Demarcq, J. Barde, E. Chassot, A. Maufroy, L. Rao-Pascuali, J.-F. Ternon, P. Verley, and C. Lett. Fish aggregating devices drift like oceanographic drifters in near-surface currents of the indian ocean. Geophysical Research Letters, in prep.

A. Maufroy, E. Chassot, R. Joo, and D. M. Kaplan. Large-scale examination of spatio-temporal patterns of drifting fish aggregating devices (dFADs) from tropical tuna fisheries of the Indian and Atlantic oceans. PLoS ONE, 10(5): e0128023, 2015. doi: 10.1371/journal.pone.0128023. URL http://dx.doi.org/10.1371/journal.pone.0128023.

A. Maufroy, D. M. Kaplan, N. Bez, A. Delgado De Molina, H. Murua, L. Floch, and E. Chassot. Massive increase in the use of drifting Fish Aggregating Devices (dFADs) by tropical tuna purse seine fisheries in the Atlantic and Indian oceans. ICES Journal of Marine Science, 2016. doi: doi:10.1093/icesjms/fsw175.