

# 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 analysis of FAD trajectories (observed and simulated) by using additional observations of Drifters and related simulations with a model (Ichthyop) driven by satellite products for sea surface currents (OSCAR). We have different goals in mind: comparisons of FADs and surface drifters trajectories (by comparing in situ observations and remote sensing data), predicting the areas where FAD could drift, prevent damages on coral reefs, check if some species are following FADs. However to deal with these use cases, the execution of thousands of simulations is a prerequisite. We propose to execute the runs of the model online with following benefits: all users can run the model remotely without having to configure anything and with additional machine resources, outputs of the model can be stored and shared online and are thus already available for the next steps (post processing). We present and discuss some of the possible use cases and preliminary results.*

**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 which 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 thus 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 parametrized with the same location and date as in situ observations. We discuss the general approach, related issues and some preliminary results. One of the main goal (and prerequisite) consists in dealing with the predictive quality of Lagrangian simulations along with the interest of running thousands of 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 which could be addressed with the information gained from FAD data and Lagrangian trajectory modelling:

- comparisons of trajectories (preliminary study):
  - 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 vs OSCAR with Drifters vs OSCAR [Imzilen et al., in prep],
  - comparisons of other kinds of trajectories: for example, 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),

- estimating the quality / uncertainty of model (Ichthyop) simulations and related products:
  - Assess first the quality of OSCAR-driven Ichthyop simulations by exploiting observations of FADs and drifters (present study) which enable comparisons between observations and simulations,
  - Quantify the uncertainty associated with Lagrangian simulations using different combinations of model (eg Ichthyop, CMS - Connectivity Modelling System-) and input data: (i) satellite images such as OSCAR and GECKO and (ii) ocean model outputs such as ROMS, Drakkar, MARS-3D, HYCOM, etc.
  - 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.
  - 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 (IOTTTP). 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),

### **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.

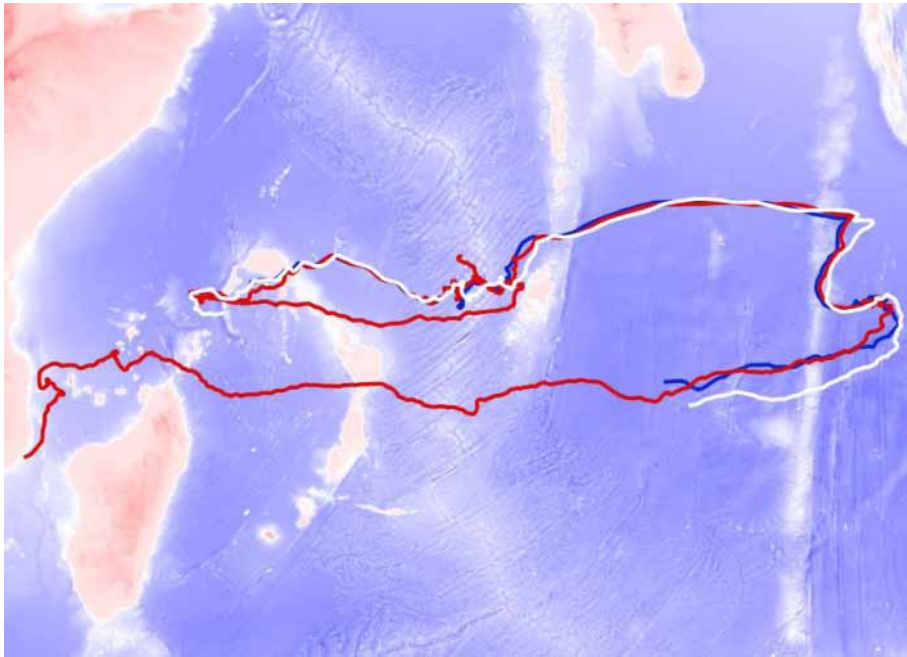


Figure 1: Trajectories of Drifters and FADs: in situ observations

### ***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 when compared to OSCAR remote sensing data.

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.

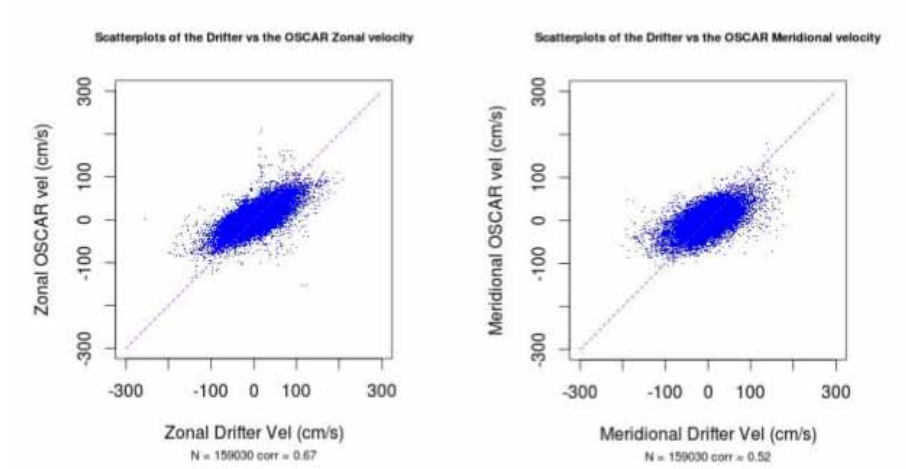


Figure 2: Comparing Drifters or FADs in situ observations with remote sensing data

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

In this section, we report our ongoing work to assess the quality of Ichthyop 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.

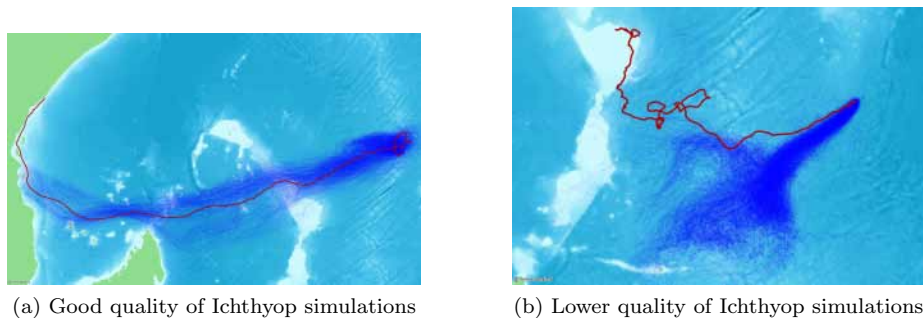


Figure 3: Example of simulation with Ichthyop: comparing observed trajectory with simulated ones

As we need to flag the quality of thousands of simulations, some basic indices

have to be created and generated by post-processing (once Ichthyop outputs have been generated) to cluster model outputs according to various criteria.

## 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 around 19000 runs (with 1000 simulated trajectories per run):

- 15000 FADs trajectories (see Figure 4a, around 22000 total),
- 4000 drifters trajectories in Indian Ocean trajectories (see Figure 4b, around 21000 worldwide).

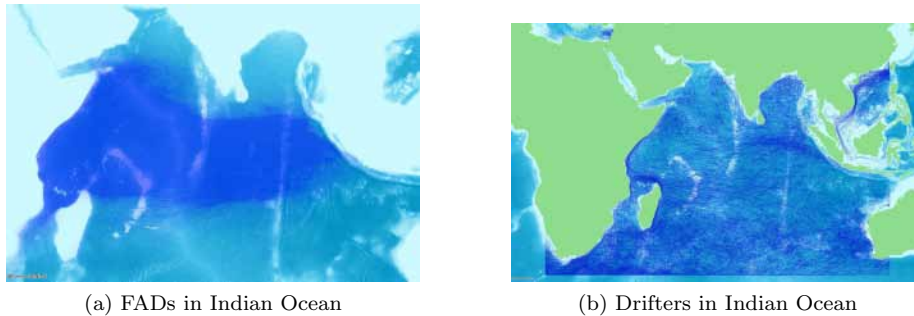


Figure 4: FADs and drifters trajectories in Indian Ocean

The mean time execution for a simulation (for Drifters or FADs) when using Ichthyop and OSCAR data through OPenDAP protocol is around 2 minutes. 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

### 4.2.1 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 simulations on the infrastructure to improve the execution time. However, since model outputs are stored in this infrastructure, accessing these data becomes a key issue if data formats and access protocols are not complying with standards.

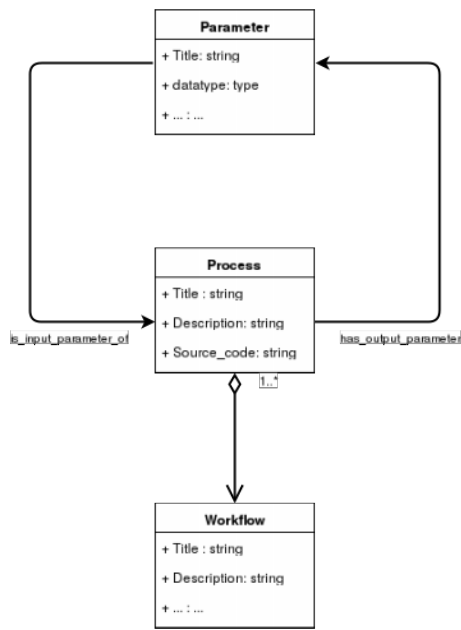


Figure 5: Workflow to run a lot of Ichthyop simulations

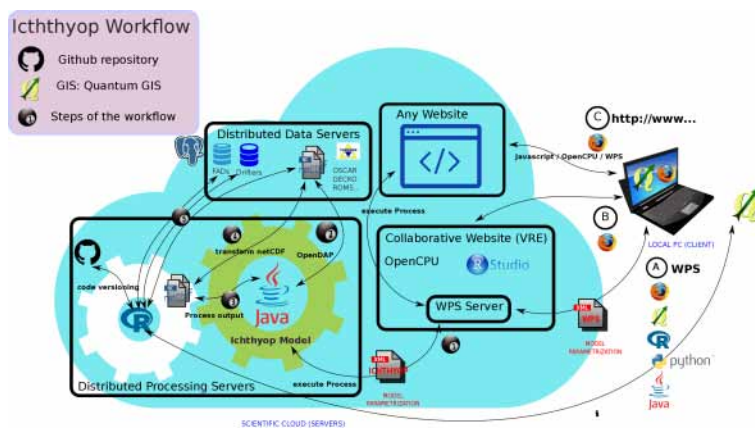


Figure 6: VRE: a collaborative Website to access services managed in a scientific cloud

#### 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 endpoint.

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 through a single endpoint (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.

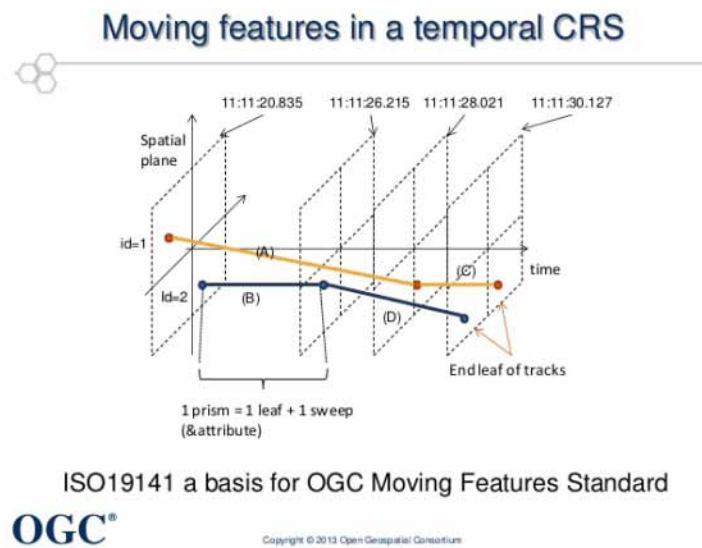


Figure 7: Standardization of data formats for moving features

## 5. Outputs and Expected products

As illustrated in Figure 8, we plan to establish a map with deployments location and related quality of simulations (function of drifting time). To achieve this



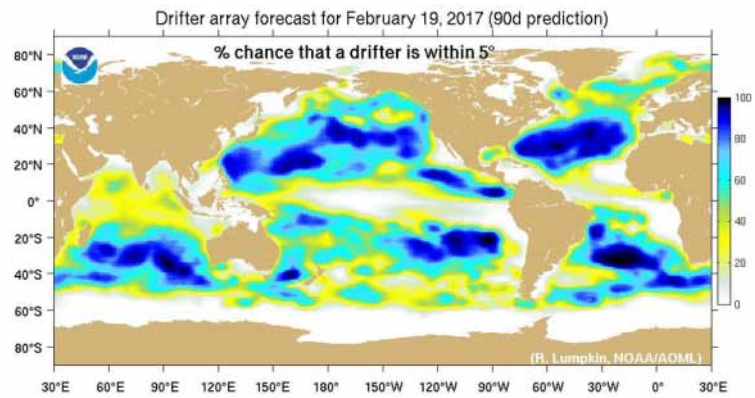
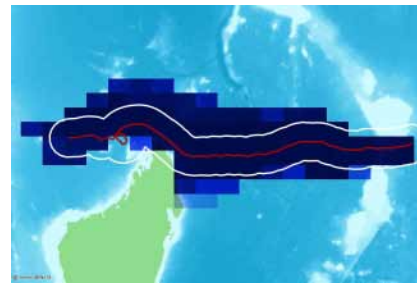


Figure 8: Example of map to predict FADs distribution areas

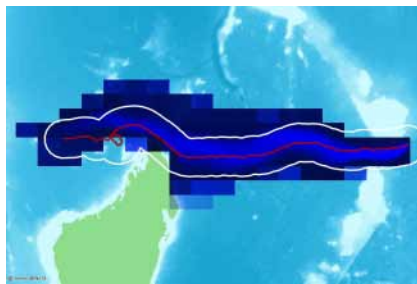
we needed to set up indices to estimate the quality of a simulation.



(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 9: Raster indices to flag the quality of Ichthyop simulations

## 6. 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't 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.

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