ORFISH - Development of innovative, low-impact offshore fishing practices for small-scale vessels in outermost regions - MARE/2015/06

WP3 Developing and testing low impact fishing techniques

Task 3.1 Transfer of Moored FADs from Guadeloupe to Azores and Madeira

Deliverable #17

Contribution of task 3.1to intermediary report

The ORFISH project

The ORFISH project aims at providing a platform for exchange of knowledge on low-impact offshore fishing techniques among fishers for the outermost regions with a view to developing and optimizing these techniques and with the principal objective of alleviating fishing pressure on coastal fish resources. The specific objectives of the project are the following:

- Raising awareness of the opportunities to develop innovative fishing techniques allowing to divert fishing effort away from coastal resources
- Developing and testing low impact fishing techniques adapted to the bio-geographical conditions of each outermost region
- Creating alternative fishing opportunities that will help to consolidate jobs in the fishing industry and ensure a steady supply of fisheries products to local markets
- Exchanging of best practice on low-impact offshore fishing techniques between ORs, which will also do good to overseas countries and territories and third countries
- Improving communication among outermost regions' fishing sectors as part of the good functioning of the Advisory Council on Outermost Regions

ORFISH website:
http://orfish.eu

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I. Introduction

In many parts of the world, including the Caribbean, Moored Fish Aggregating Devices (MFADs) are increasingly being used locally by small-scale fishers to access fish species otherwise difficult to harvest in large number. FADs are manmade structures designed to float on or near the surface, attract fish and facilitate their capture. Moored FADs create resource patches at known locations, significantly reducing search time, effort, and fuel costs for fishers. Moored FAD development programs are seen as a way to increase the income of small-scale fishers, improve livelihoods in fishing households and communities and reduce fishing pressure on continental shelves by encouraging redeployment of fishing effort to MFAD. Moored FADs are distinguished from drifting FADs operated mainly by large scale offshore fleets in the inter-tropical Pacific, Indian and Atlantic Ocean.

In Martinique and Guadeloupe, MFADs were experimented in the 80’s and a significant part of the small-scale fleet in these ORs is involved in MFADs fisheries. Azores and Madeira carried out MFADs experiments in the 90’s but without significant monitoring and concrete results. Lesser Antilles area and especially Guadeloupe and Martinique have developed skills on MFADS over the last 20 years and more recently through the Interreg Magdelesa Project, especially on MFAD technology.

II. Objectives:

The main goal under this task is to carry out a transfer of technology on MFADs from Guadeloupe to Azores and Madeira.

III. Transfer of MFAD from Guadeloupe to Azores

3.1.1 Context analysis

The first phase of the Task 3.1 concerned the collection and analysis of information and data about Condor Bank Seamount.

Condor Bank Seamount is a large linear volcanic ridge located in the subtropical central Atlantic in the immediate vicinity of the southern coast of Faial island (Azores archipelago). In the last nine years, it has been the target of an intense scientific programme aiming to improve our understanding of seamount structure and functioning from the sea surface down to the seafloor (Giacomello *et al*., 2013).

Data derived from multi-beam and from moorings and CTD cast (Conductivity/Temperature/Pressure) at different depths (Tempera *et al*., 2013; Bashmachnikov *et al*., 2013) were analysed.

Condor seamount is a volcano of elongated shape with the top relatively flat and smooth, sedimentary flanks, and east-west orientation. On the west summit, the shallower zone of the seamount, the occurrence of rounded boulders indicate that this area has been exposed to surface waves, when sea level was about 120 m below current levels. The Condor seamount is around 1800 m high, 39 km long and 23 km in wide, extending from 185 to 2003 m depth. With its 493 km^2, it is currently a Marine Protected Area (MPA) managed by the Government, under special permit for pelagic species and under scientific monitoring by the Azores University on currents, sediments, stock assessment and seafloor mapping. Bottom fishing activities are interdicted within the limits of the MPA.

Due to the fact of being an MPA with legal restrictions on fishing and by being used as a living laboratory, this area has been indicated to be the best spot where to test, to assess and to monitor the MFAD technology in the Azores. This is a compulsory step before moving on to the legislative and regulatory aspects of fishing activities related to this technology in the Azorean waters outside MPAs boundaries.

3.1.2 MFAD setting and building

Considering the characteristics and the needs of the traditional artisanal fleet and following the conclusions of the first and unique MFADs experiment in the Azores (Pinho, M. R. & J. Pereira, J., 1995; Pinho, M. R. & Pereira, J., 1995), the location for the MFAD was selected in the central group of the archipelago and near the shore (at a distance of 6.5 nm).

In order to choose the place where to put the MFAD, geomorphological data (e.g. substrate type, slope, bathymetry), the distance from the fishing harbour, primary productivity of the area (considering also opinion of local fishermen), the nature and profile of the sea bottom, information on currents and the dispositions of University' devices (including fishing sets) were taken into consideration.

After the permit from the Government and the endorsement of the Port Authority of Faial, the information about the location of the MFAD device was passed to the subcontracted expert on MFAD in order to assess if the position was good and to define the characteristics of the MFAD to be built for that depth (1113m) and sea conditions. The report of the expert is presented in Annex 1.

The place selected (38° 33'N; 28° 54' W) was appropriated for the objectives of the MFAD' experiment and, after modelling, the MFAD was designed.

It will be composed by: a floating cable (1000m length), a sinking cable (300m length), a reinforced cable (200m length), and another floating cable (60m length) with 46 floaters (11liter each) and a flag buoy with radar reflector and light position, all supported by one concrete anchor (1ton).

All the equipment for the building of the MFAD is ordered and its building and mooring will take place, depending on sea and weather conditions, in the first two weeks of June 2018. These operations will be supported by the partners from Guadeloupe.

All the logistic and the technical aspects about the building and the subsequent launch of the MFAD have been agreed and decided both with the Government Authorities of the Azores, the Guadeloupean team and the University of the Azores.

The construction of the concrete anchor will be concluded by the end of May 2018. The assembly of the equipment for the construction of the MFAD will start as soon as the equipment will arrive in Faial island and it should be ready by the first two weeks of June 2018.

3.1.3 MFAD monitoring and reporting

The onsite monitoring of the MFAD will be performed using three methods: 1) Once per month one boat will take seaExpert team at sea and spend all day fishing and sampling catches; 2) The same boat will have a special permit for fishing within Condor Bank MPA and will be monitored by the beacon installed and will have a special form to fill whenever he will fish in the MFAD area; C) The MFAD structure will have a buoy with echo sounder incorporated.

IV. Transfer of MFAD from Guadeloupe to Madeira

4.1.1 Context analysis

The first phase of the Task 3.2 concerned the collection and analysis of information and data about the coastal and the offshore area of the Island of Madeira.

After the permit from the Government and the endorsement of the Port Authority of Madeira, the information about the location of the MFAD device was passed to the subcontracted expert on MFAD in order to assess if the position was good and to define the characteristics of the MFAD to be built for that depth (710.5m) and sea conditions.

4.1.2 MFAD setting and building

Considering the characteristics and the needs of the traditional artisanal fishing fleet in the archipelagos of Madeira, the location for the MFAD was selected near the shore of Madeira Island (32°42'25.20'' N; 16°43'4.80'' W) at approximately 710.5 m deep.

It will be composed by: a floating cable (500m length), a sinking cable (300m length), a reinforced cable (200m length), and another floating cable (21m length) with 42 floaters (11liter each) and a flag buoy with radar reflector and light position, all supported by one concrete anchor (1ton).

All the equipment for the building of the MFAD is ordered and its building and mooring will take place, depending on sea and weather conditions, by the second half of June 2018. These operations will be supported by the partners from Guadeloupe and Azores.

4.1.3 MFAD monitoring and reporting

The monitoring procedures that will be decided to adopt for the MFAD in Madeira, it has to be decided yet. But it will be aligned as much as possible with the monitoring of the MFAD that will be launched in Madeira. This will guarantee the possibility to compare the two experiments, with an expected scientific paper as an output, in order to share knowledge, highlighting the main findings and lessons learnt and to point ways forward.

4.2 Transfer of knowledge

The transfer of knowledge among the partners took place at the Workshop #2 held in the Azores in March 2018.
During the Workshop there have been meeting and sharing of the data and information collected until that moment between the partners in order to coordinate the following steps towards the building and launching of the MFADs in Azores and Madeira.

V. Annex 1: Calculation and modelling of the MFAD in the Azores

TABLE DES MATIÈRES

- ABSTRACT

FADs have been used in the Caribbean for decades.

Over the years we have tried to improve the models of FADs with the constant objective to increase their efficiency and their lifespan while maintaining a reasonable cost.

The two main objectives that can be solved by calculation and modeling are:
1: no part of the anchor line must be on the surface or rest on bottom when there is no current
2: the FAD must withstand the strongest currents existing in the area.

Calculation and modeling are based on the physical characteristics of the FAD, mainly the buoyancy of the float (s), the diameter, the length and the density of the various ropes of the anchor line.

From the depth of the installation site, calculations will lead to choices that will be appropriate for the first objective.

Once the set of characteristics has been defined, the FAD can be modeled in the "DCP" software developed by IFREMER and its behavior analyzed in different current configurations.

The currents extracted from COPERNICUS data make it possible to define a theoretical maximum possible current on the laying zone.

Applying this current to model we will be able to analyze and modify choices made in the design of the FAD.

We present and detail the calculations and the results of the modelizations which lead to the proposal of a detailed plan of the FAD.

- POSITION OF FAD, DETPTH

We remind the main criteria of choice for a DCP site:

- SITE SELECTION CRITERIA

The site selection will depend on:

- The opinion of local fishermen and their knowledge of the productivity in the area
- The distance from the fishing harbor(s) and fish landing sites
- The location of the busiest commercial harbors and shipping lanes
- The nature and profile of the sea bottom
- The presence of other FADs in the area
- The depth of water
- The presence of undersea cables
- …

- FAD POSITION

The FAD position chosen by the Azorean partners is:

In decimal degrees

Latitude :	38.551899°
Longitude :	-28.905300°

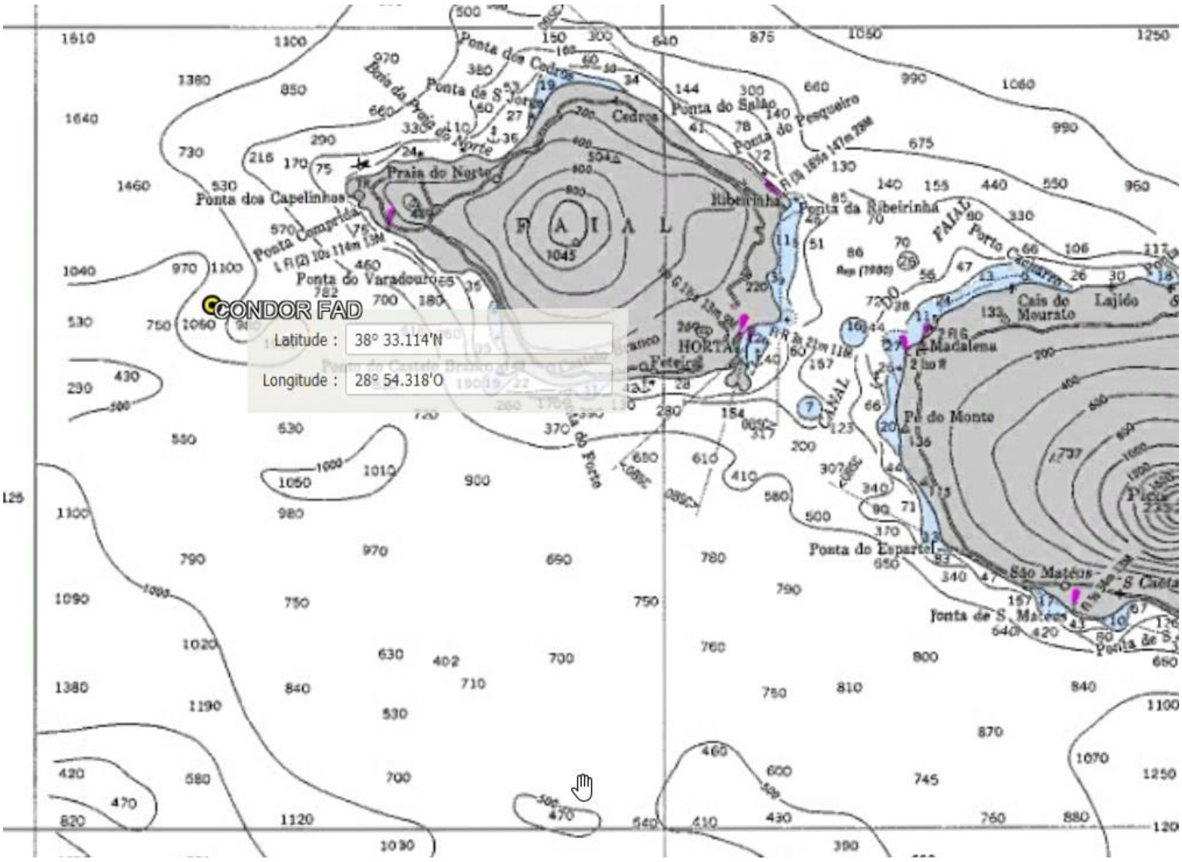
In degrees and decimal minutes

Latitude :	38° 33.114'N
Longitude :	28° 54.318'O

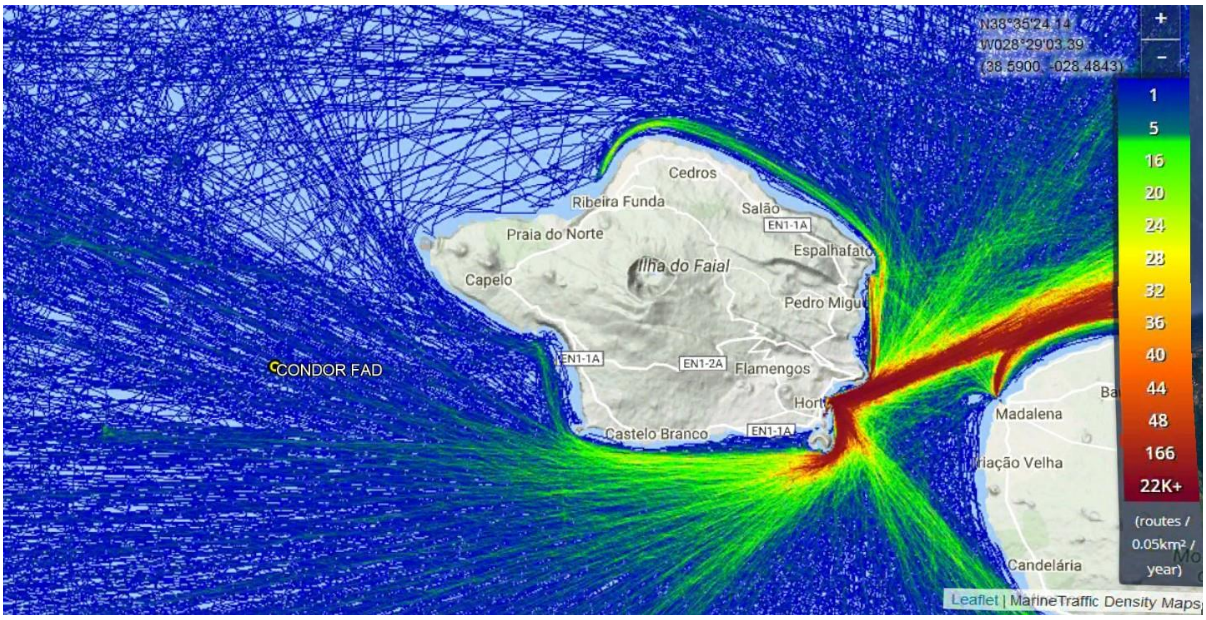
- DEPHT

The depht in this position is 1113 meters

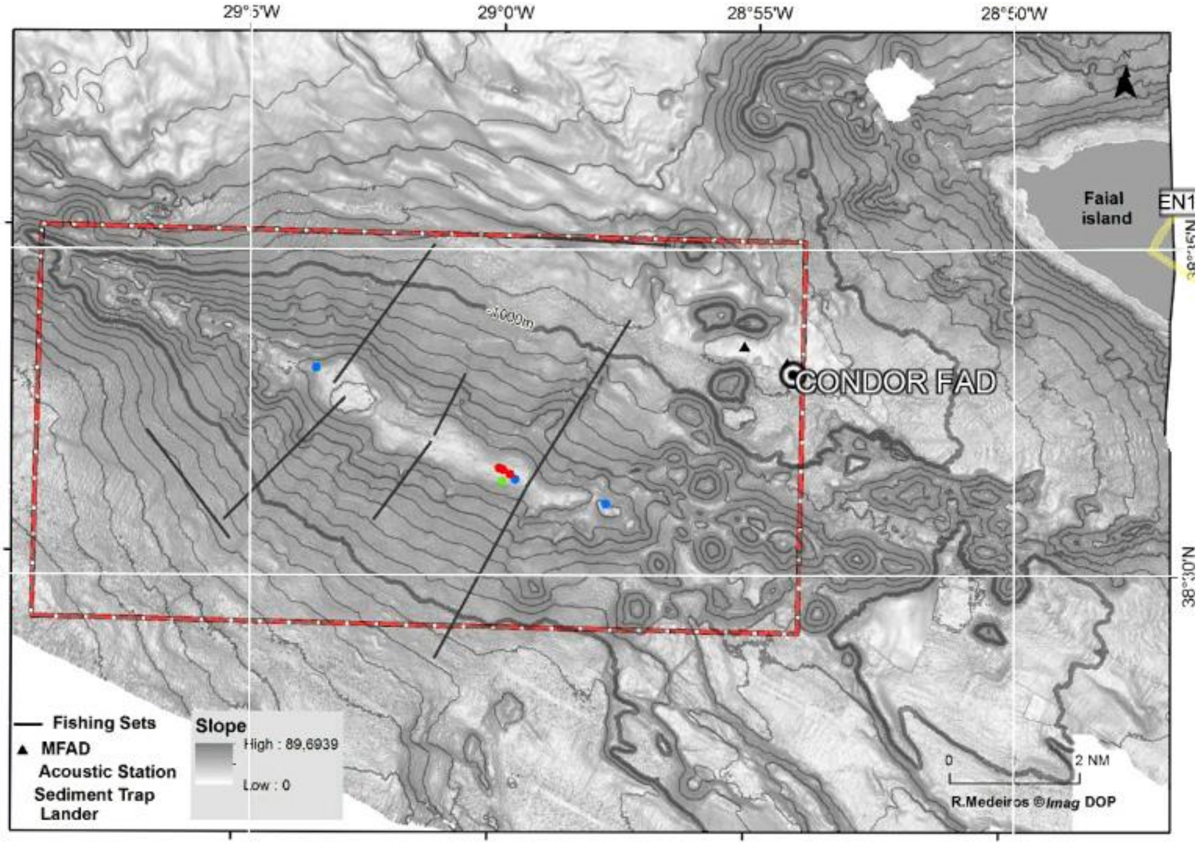
- CONDOR FAD ON NAUTICAL MAP



- CONDOR FAD POSITION ON DENSITY OF TRAFFIC MAP



- CONDOR FAD POSITION ON SLOPE MAP

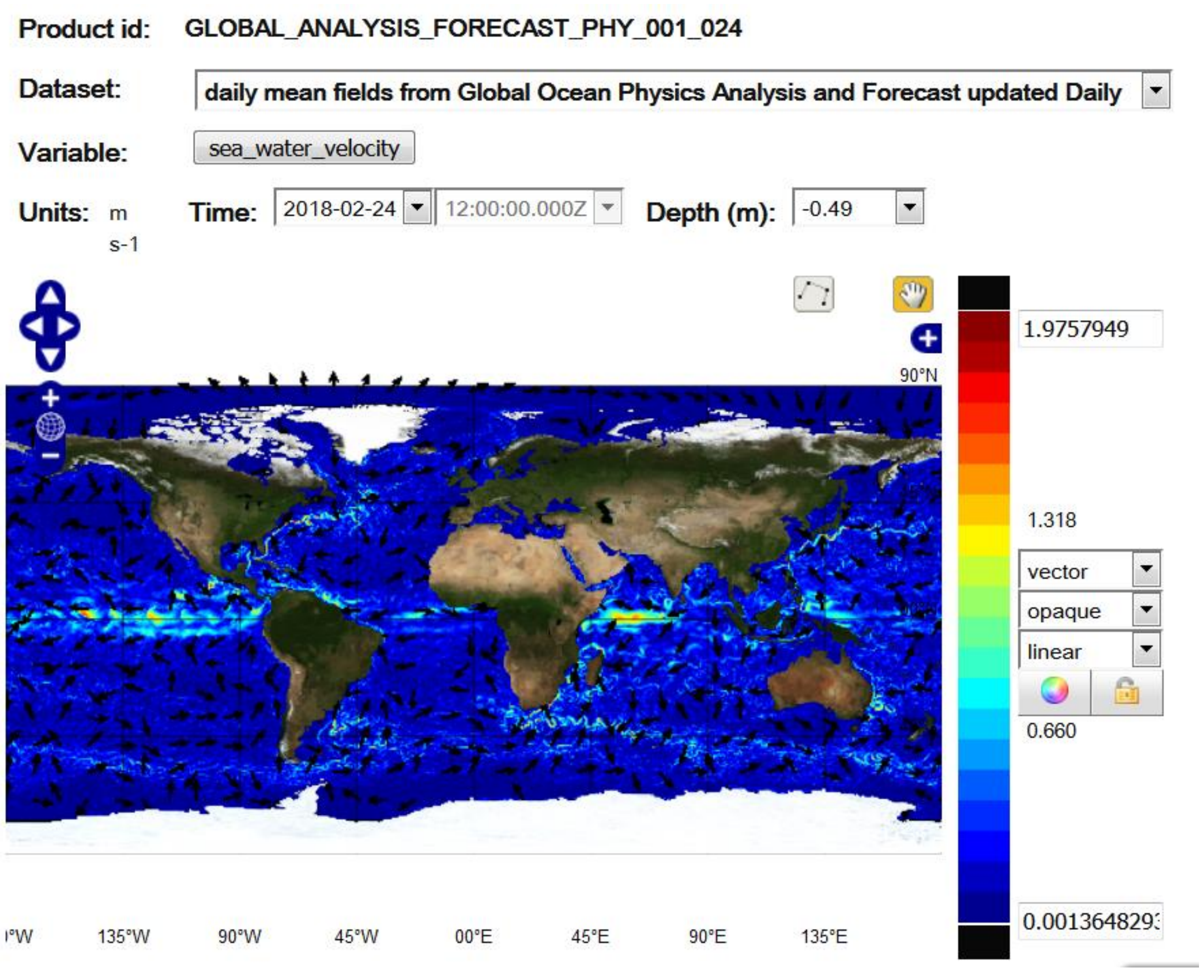


Bathymetry data Credits: EMEPC, DOP-UAç, projecto STRIPAREA/J.Luis/UAlg-CIMA, Lourenço et al., 1998.

- SETTING THE MAXIMUM CURRENT PROFILE AT THE FAD POSITION

Currents are extracted from copernicus databases:

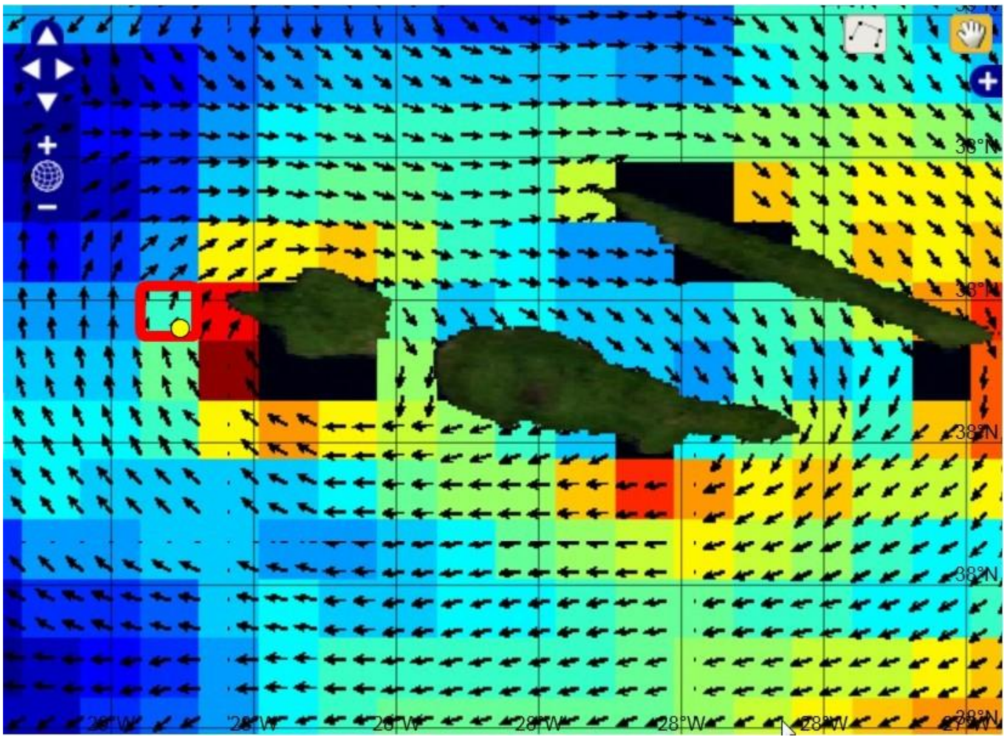
http://marine.copernicus.eu/services-portfolio/access-to-products/?option=com_csw&task=results&advancedsearch-geographical_area[]=advancedsearch-geographical_area-global-ocean



Copernicus physics analysis data

Velocities and direction of current are available at each point for different depths since the year 2006

- CONDOR FAD POSITION ON COPERNICUS GRID

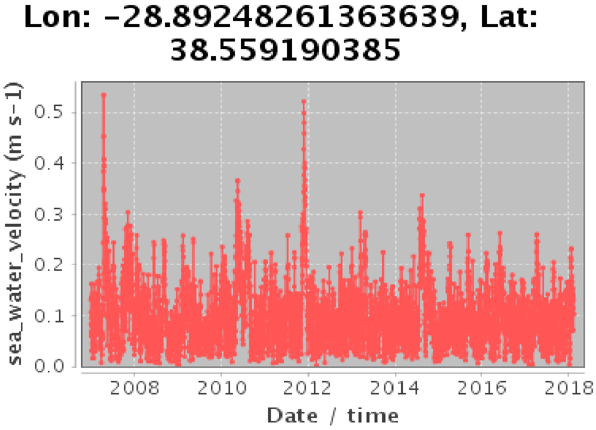


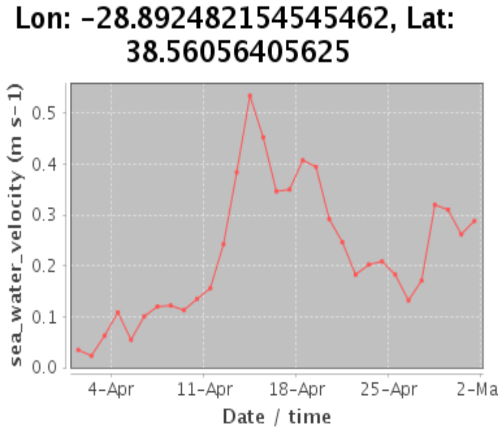
Tiime series allow to extract the maximum current speeds over the duration of the database (12 years) for the following depths:

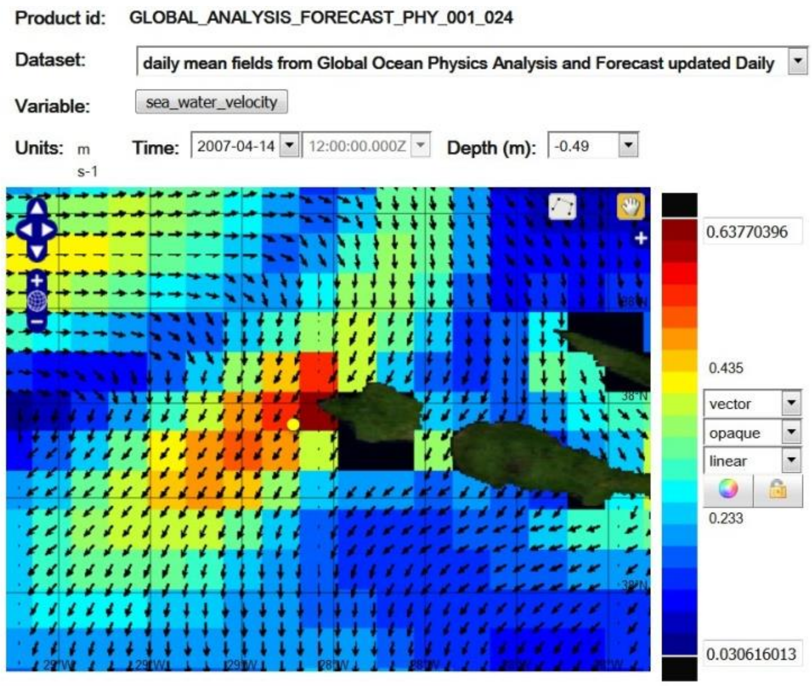
- Surface
- 50 m
- 100 m
- 200 m
- 300 m
- 500 m
- 900 m
- 1100 m

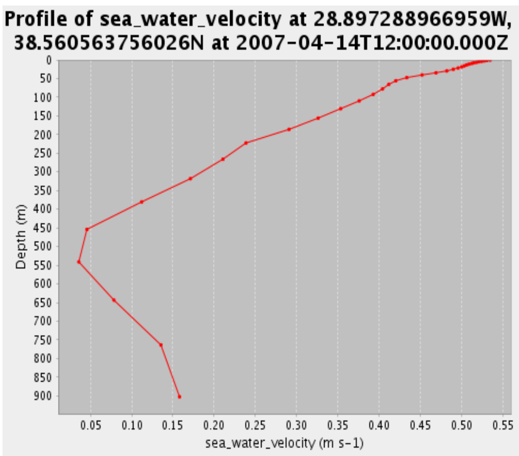
- - SURFACE MAXIMUM CURRENT

On the surface the maximum current happened on April 14, 2007
the speed of the maximum surface current is 0.54 m / s



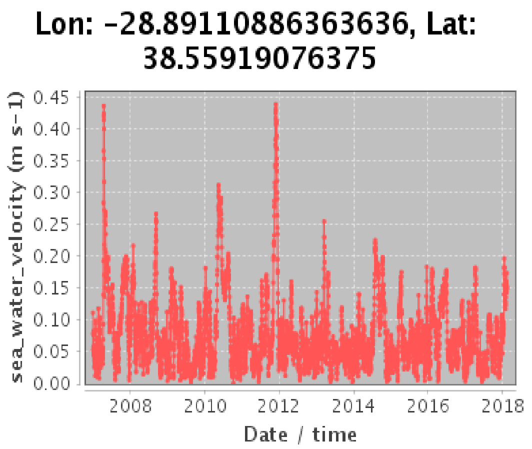






- - 50 METERS MAXIMUM CURRENT

At -50 m the maximum current happened on April 15, 2007
the speed of the current was 0.45 m / s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0.00
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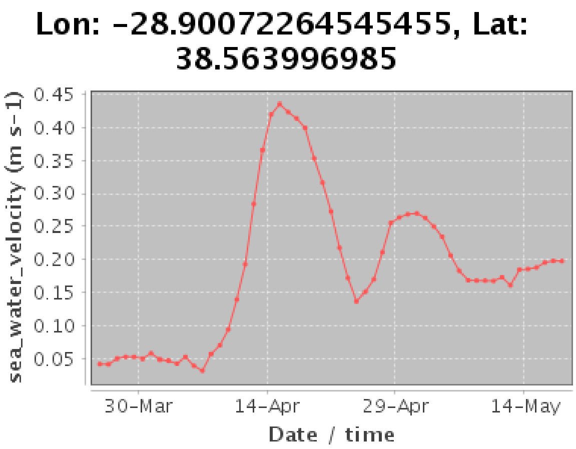
2010
2012
2014
2016
2018
Date / time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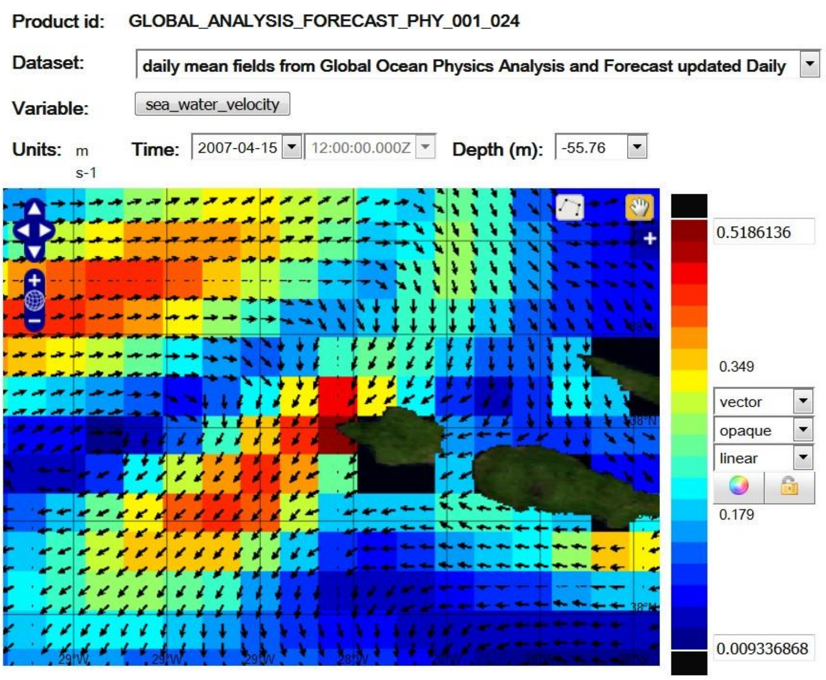
30-Mar
14-Apr
29-Apr
14-May
Date / time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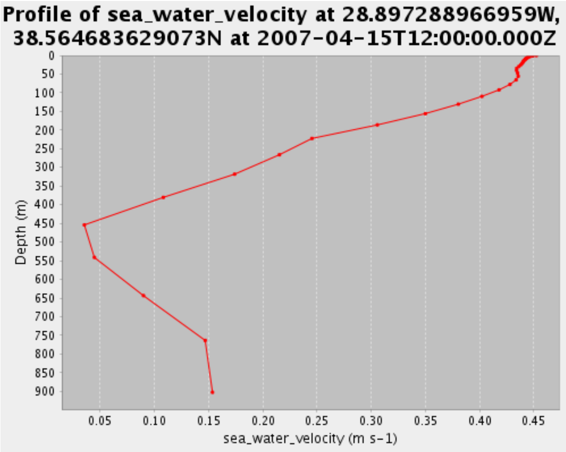
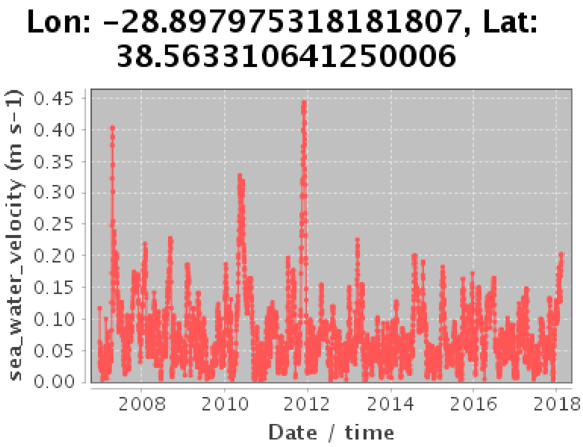
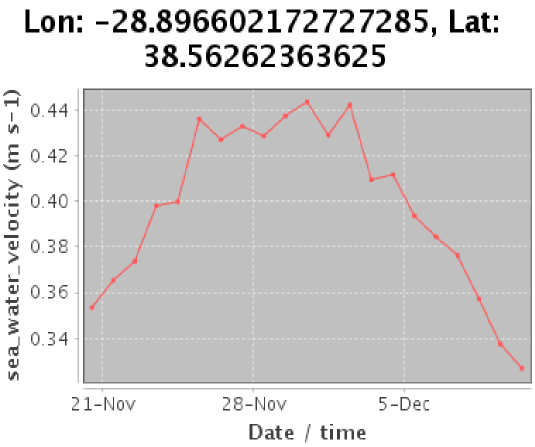
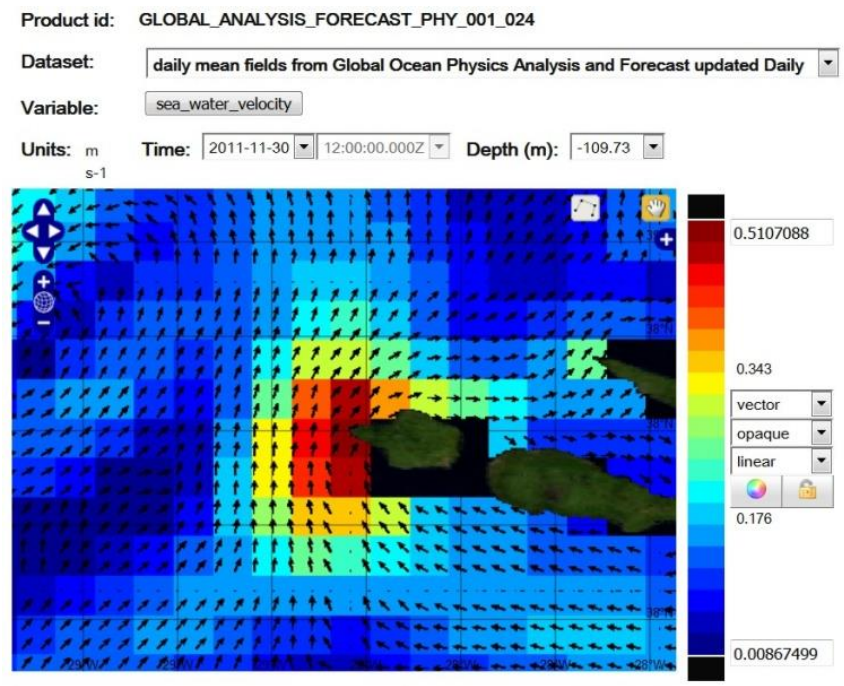


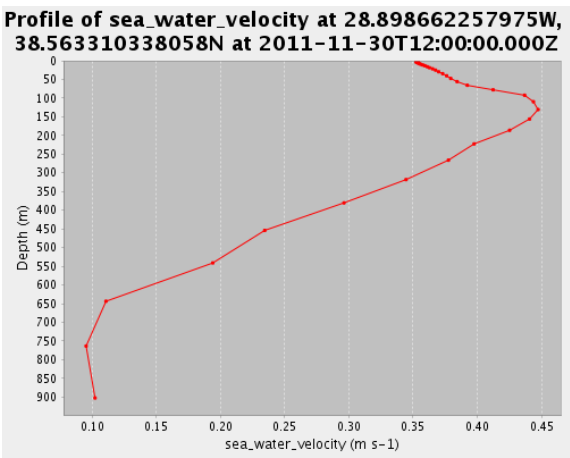
- - 100 METERS MAXIMUM CURRENT

At -100 m the maximum current happened on Novembre 30, 2011
The speed of the current was 0.44 m / s



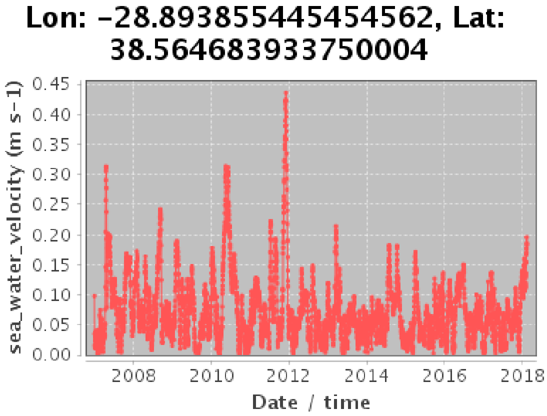


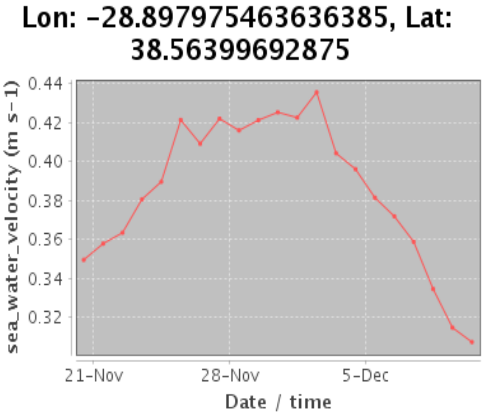


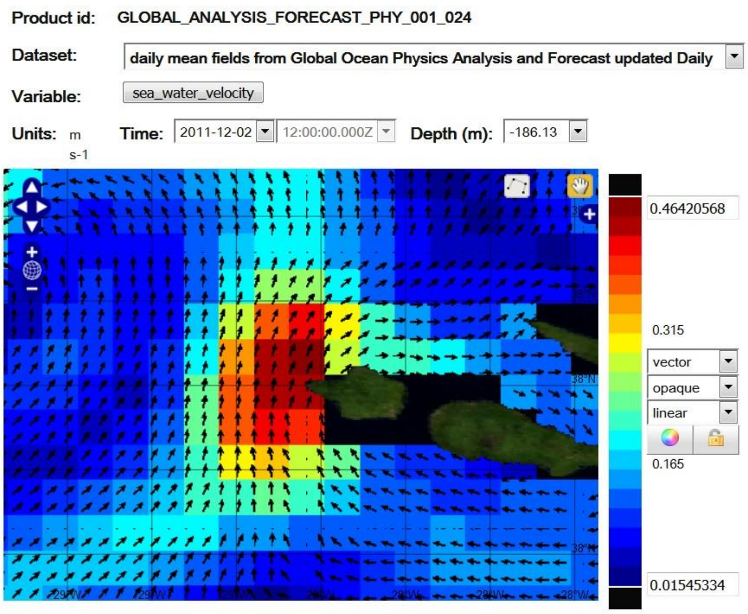


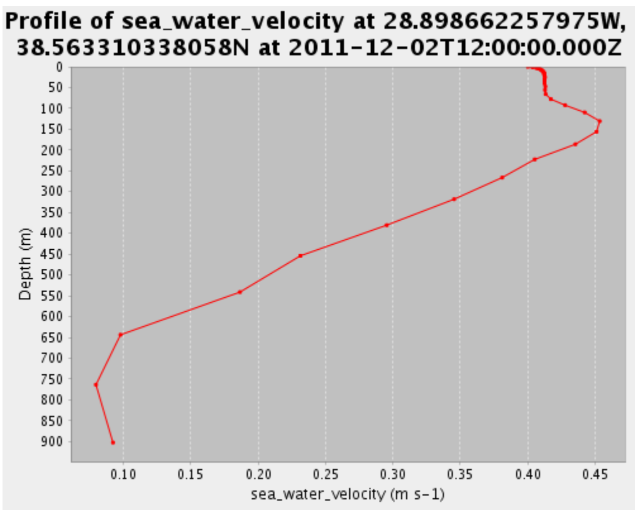
- - 200 METERS MAXIMUM CURRENT

At -200 m the maximum current happened on Decembre 2, 2011
The speed of the current was 0.44 m / s



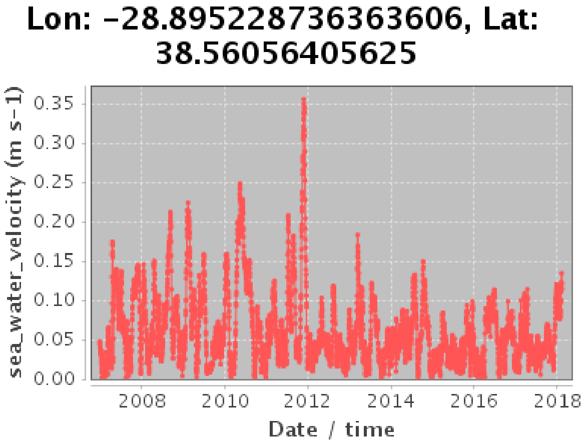


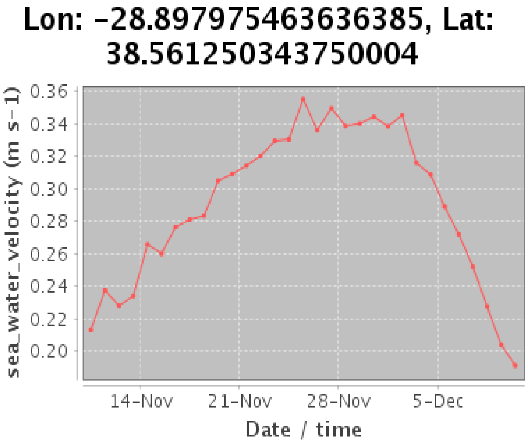


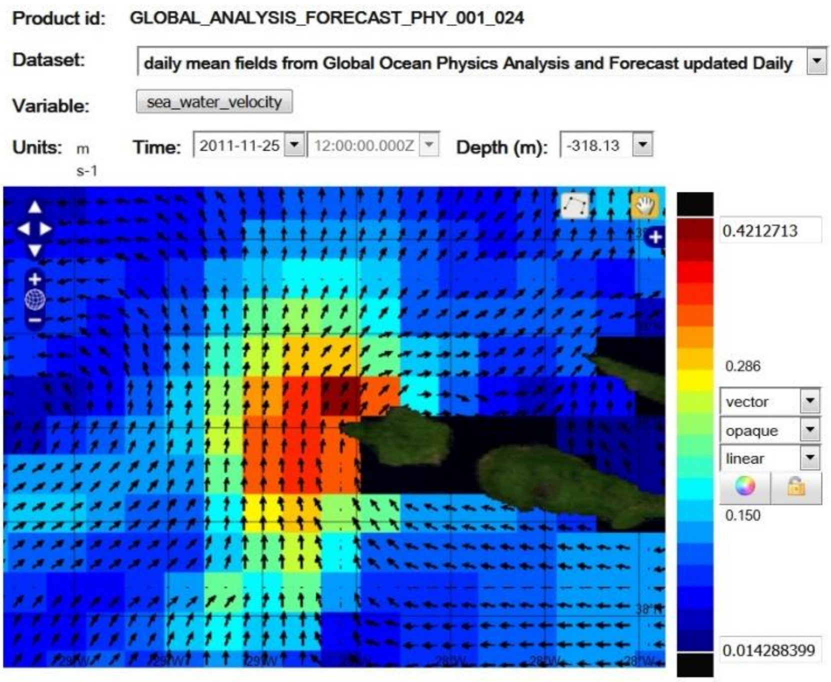


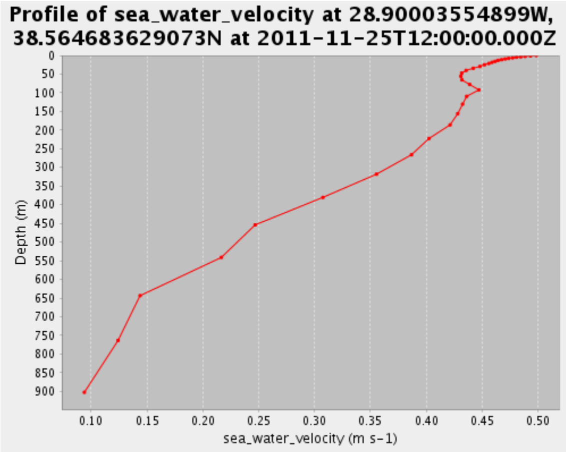
\- - 300 METERS MAXIMUM CURRENT

At -300 m the maximum current happened on Novembre 25, 2011
The speed of the current was 0.36 m / s



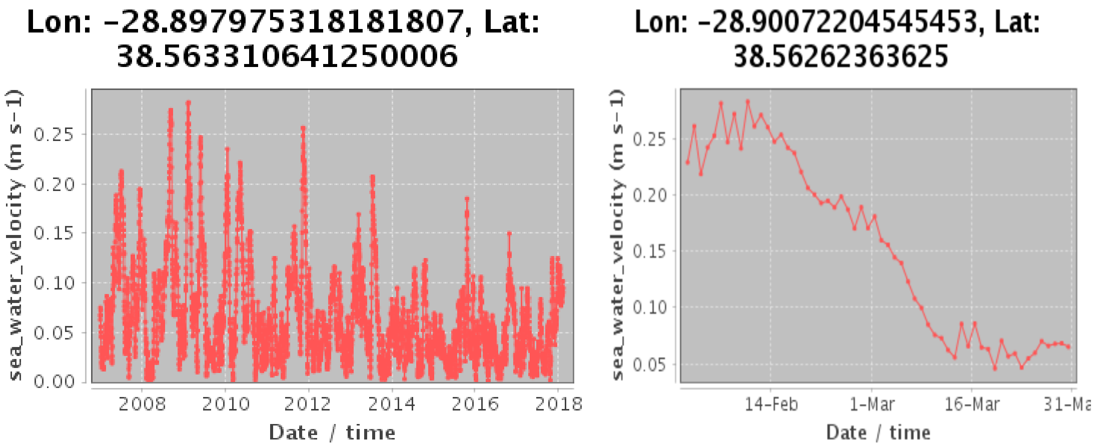


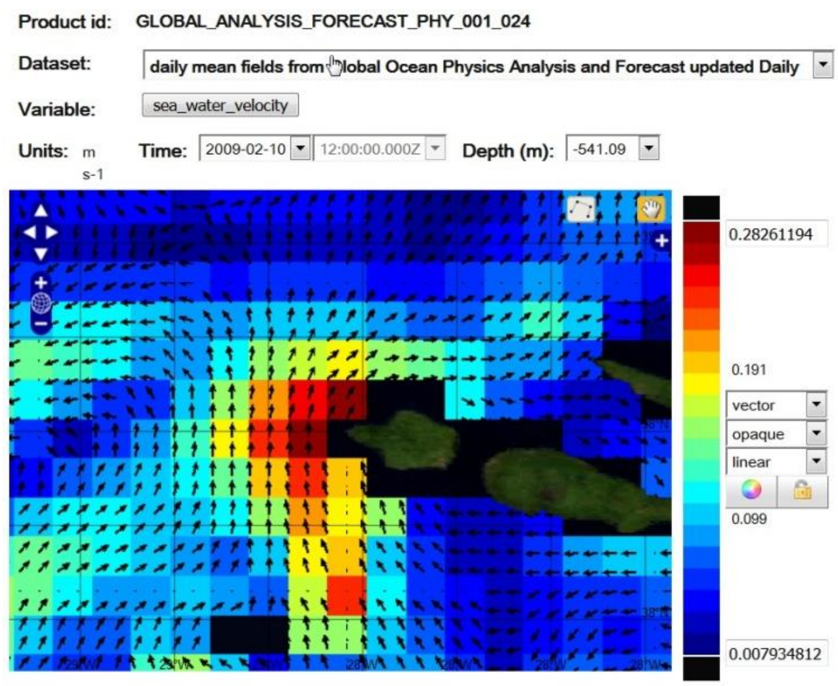


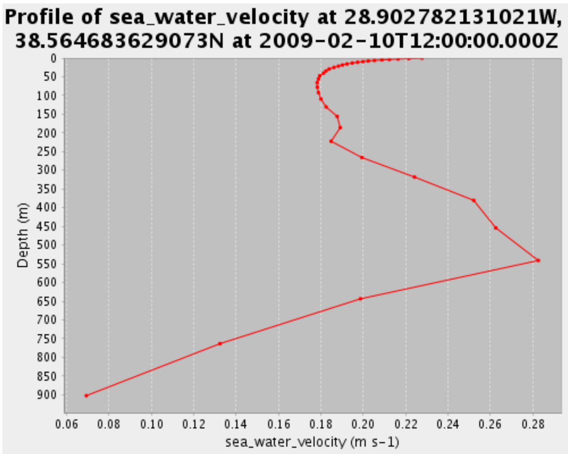


- - 500 METERS MAXIMUM CURRENT

At -500 m the maximum current happened on Fevrier 10, 2009
The speed of the current was 0.28 m / s

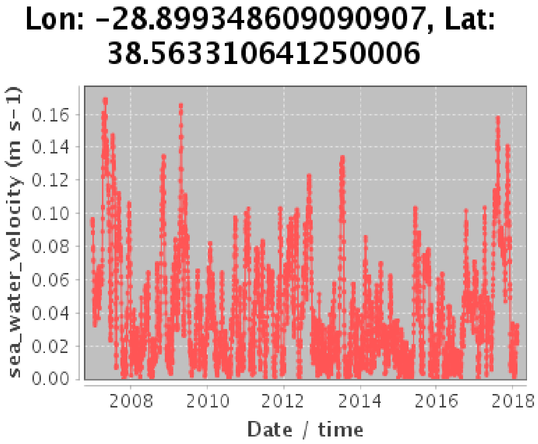






- - 900 METERS MAXIMUM CURRENT

At -900 m the maximum current happened on Avril 28, 2007
The speed of the current was 0.17 m / s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2016
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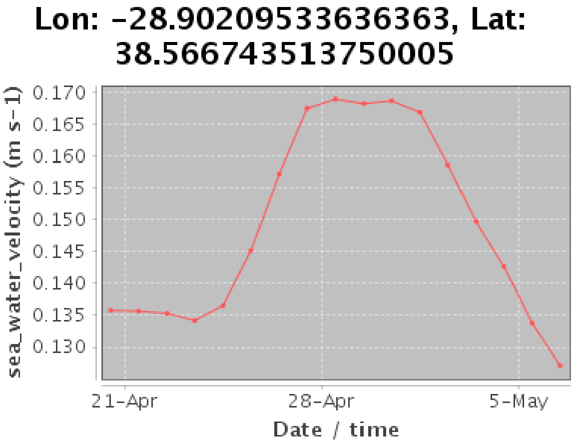
Date / time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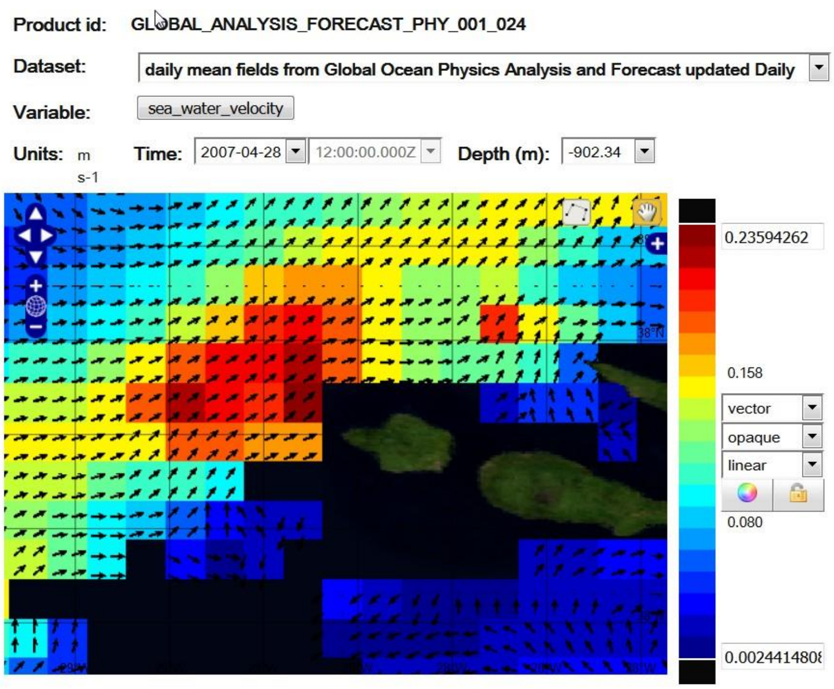
Date / time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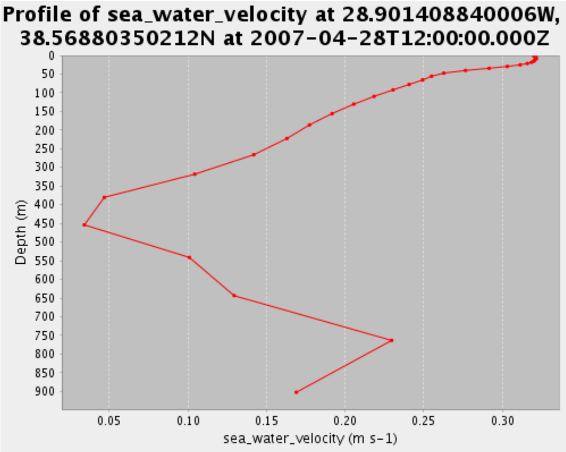
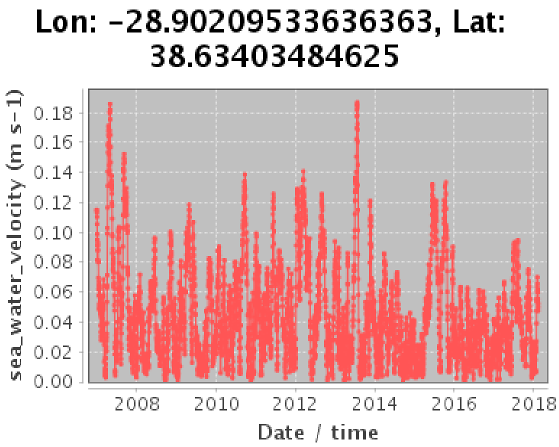
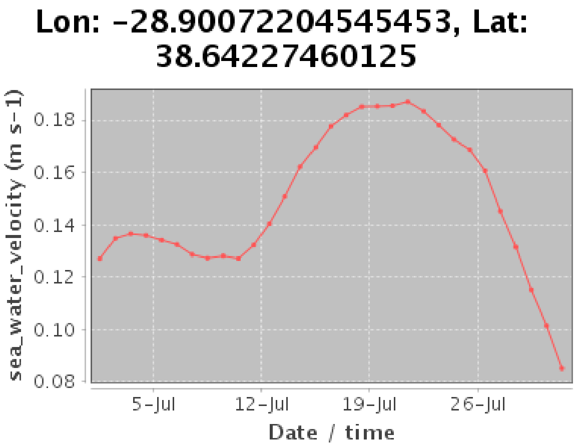
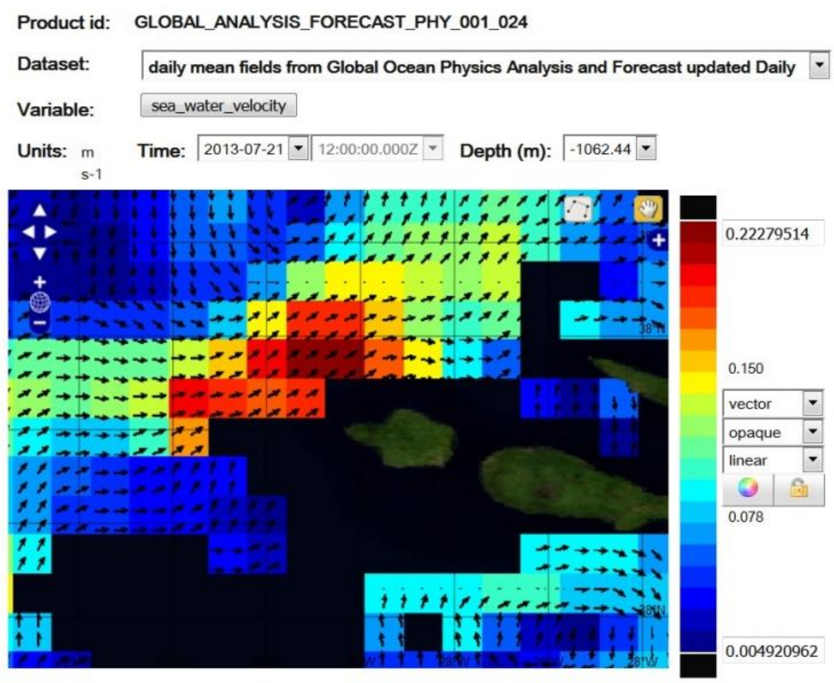


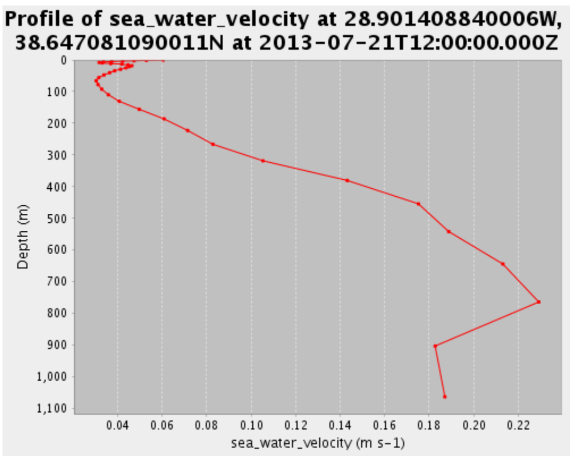
- - 1100 METERS MAXIMUM CURRENT

At -1100 m the maximum current on Juillet 21, 2013
The speed of the current was 0.19 m / s



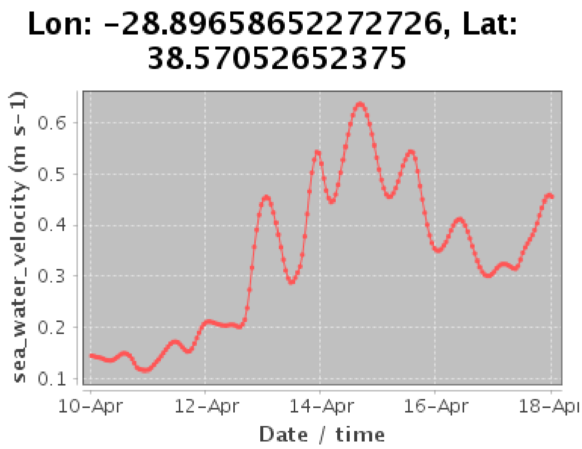


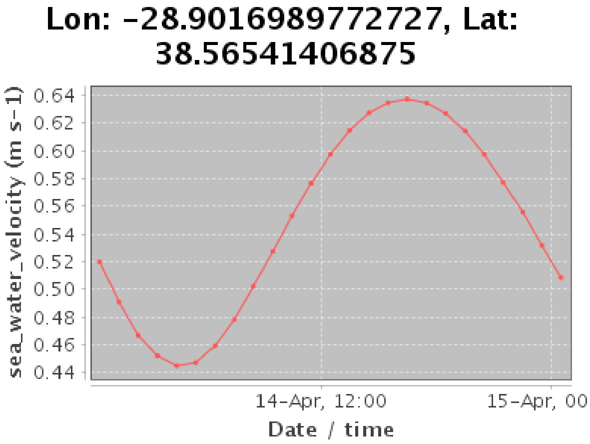


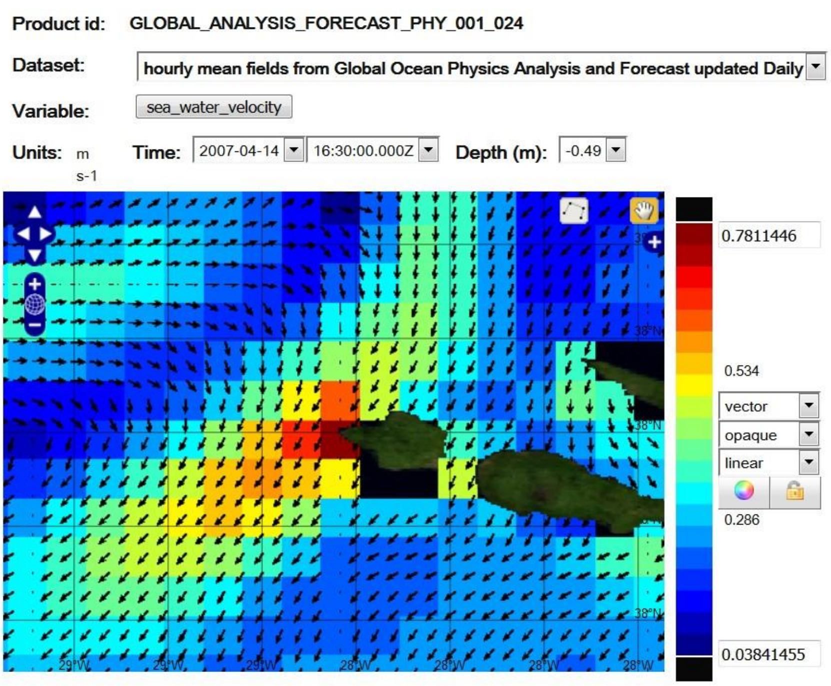


- TIDAL EFFECT ON THE SURFACE CURRENT

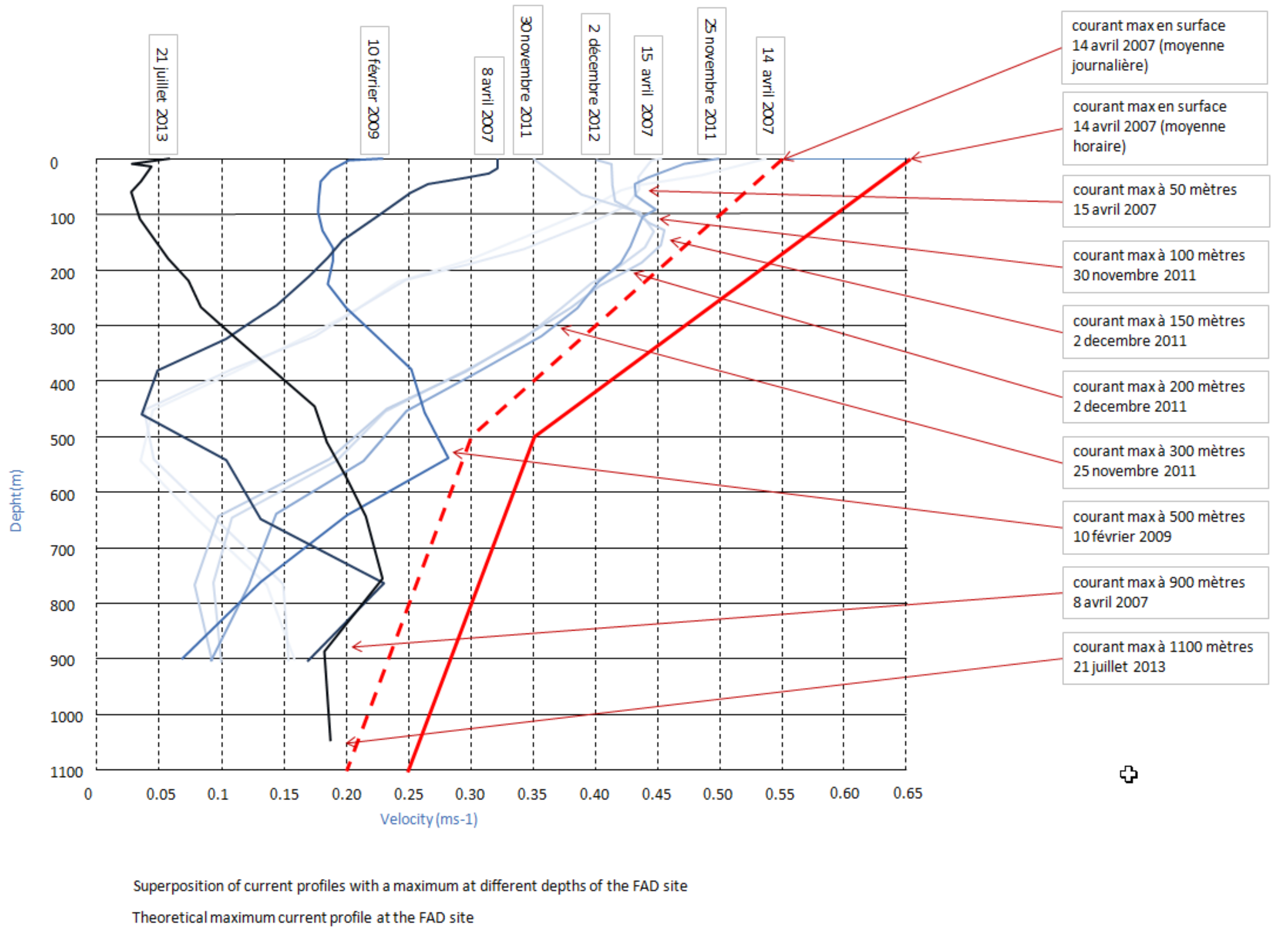
On the surface the maximum current happened on April 14, 2007 at 16:30
the speed of the maximum surface current is 0.64 m / s







- THEORICAL MAXIMUM CURRENT USED FOR MODELISATION OF THE FAD



The maximum current used for modelisation of the FAD is defined by the table:

Depht(m)	*Current velocity (m/s)*
0	0.65
500	0.35
1100	0.25

The current varies linearly between these points.

- COMPARISON WITH BASHMACHNIKOV STUDY ON CONDOR BANK

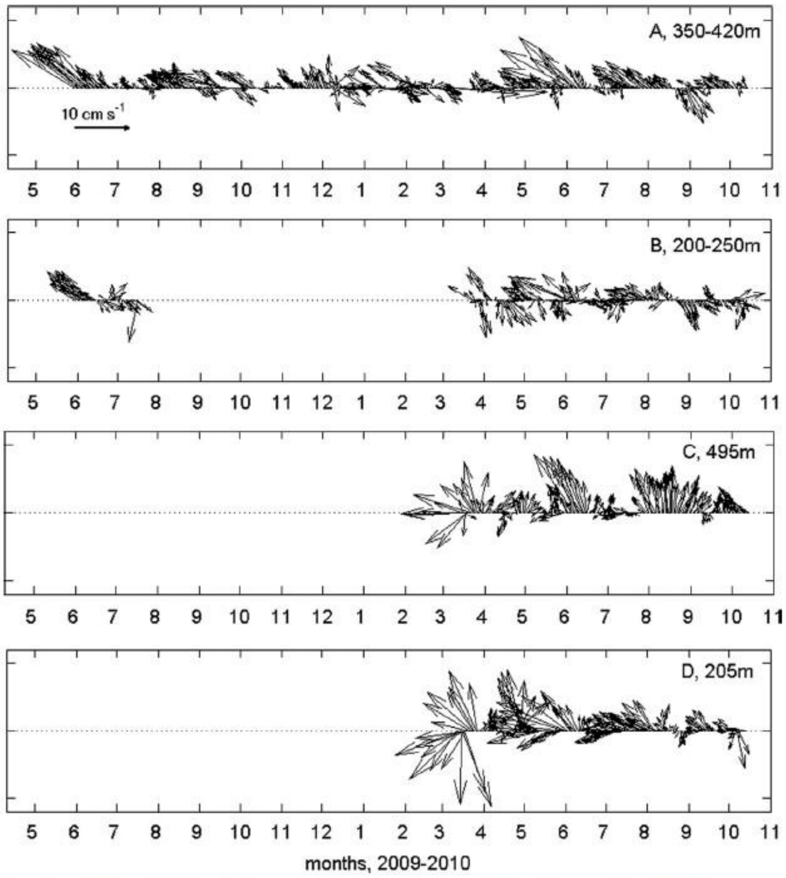


Fig. 2. Feather plots of tide-filtered daily current velocities (cm s^{-1}) at moorings A (350–420 m), B (200–250 m), C (495 m) and D (205 m).

Table 4
Distributions of modulus of daily mean current velocity (in %). The distributions in the corresponding depth levels at moorings A, B, C and D are nearly identical, their average is referred to as "Condor" distribution.

Source of data	0–5 cm s^{-1}	5–10 cm s^{-1}	10–15 cm s^{-1}	> 15 cm s^{-1}
T, 170–220 m	7	23	27	43
Condor, 150–350 m	50	36	11	3
Condor, 400–500 m	67	22	8	3
Condor, 800–900 m	93	7	0	0
S, 300 m	43	48	9	0
S, 650 m	79	19	2	0
S, 950–1200 m	96	4	0	0
AVISO (1993–2010)	52	40	8	0

The current data of the study of Bashmachnikov are consistent with the data obtained from the Copernicus database.
It should be noted that the maximum currents identified in the Copernicus database are much higher than the average currents and that they appear with a low frequency, which explains why these currents seem to be higher than those recorded by the bashmanikov study. These are the maximum currents that must be used for modeling to shelter from a period of strong currents of exceptional intensity.

- CONCLUSION ON CURRENTS

The maximum current for the modeling assumes that all the maximum currents found at the different depths happens at the same time, which does not correspond to reality. On the contrary, the profiles obtained show that the strongest deep currents correspond to weak surface currents.

This hypothesis causes the modeling current to already have a good safety coefficient compared to the actual currents that may exist.
Although the selected area appears to be in the sector where the currents are strongest (probably because of the proximity of the island and the Condor Bank) these currents remain rather weak in comparison with the Caribbean current, strengthened by the equatorial northerly current and the Guyana current.
This moderate current makes it possible to orient some choices concerning the FAD:
A buoyancy of 400 liters should be sufficient and the diameter of the ropes could be increased to 20 mm as the laying depth (1100 m) is not too deep.

- CALCULATIONS OF THE FAD CHARACTERISTICS

- CALCULATION OF ROPES LENGTHS

- BASIC DIAGRAM OF A MOORING LINE (WITHOUT CURRENT)

- CHARACTERISTICS OF THE FAD, INITIAL DATA

The calculation is a modeling of the behavior of the buoy rope of a “sinking then floating rope” FAD when there is no current at all.
It enables you to obtain the length of the floating and sinking ropes depending on the depth, total length of the anchor line, characteristics of the ropes and desired depth of the top of the loop.
The depth of the top of the loop is meant to protect the ropes from the deepest fishing gears. The total length of the anchor line is defined by the ratio between the depth and length of the line. In the calculation, only the relative density and linear mass of the ropes in the loop arm matter. The characteristics of the ropes must not change in the loop arm. The characteristics of the ropes in the ascending arm and in the descending arm don’t intervene, provided that they are respectively floating and sinking. The variables are:

- The depth
- The ratio between the total length of the line and the depth
- The depth of the top of the loop
- The relative density of the water

(Green cells in the calculation table)
and

- The linear weight and density of the ropes used

(Orange cells in the calculation table)
Local currentology data and experience of the FADs used in the Caribbean allows to make the initial choices of the characteristics of the FAD

data	
depht	1100 meters
ratio	1.4
top of the loop depht	250 meters
floating rope	polypropyléne or copolymere
diameter	20 millimeters

linear mass	18 kilogrammes/100 meters
density	0.92
sinking rope	polyester
diameter	20 millimeters
linear mass	30.3 kilogrammes/100 meters
density	1.38
Combination rope	polypropyléne and steel
diameter	16 millimeters
linear mass	34.1 kilogrammes/100 meters
Density PP	0.92
Density steel	7.8

- LINEAR WEIGHT AND DENSITY OF CHOSEN ROPES

These data may vary slightly depending on the manufacturer

Linear weight of a polypropylene rope of diameter 20 mm

Diam. Ø	Circ.	Mass	Min. breaking load	
mm	inch "	kg/100m	T	kN
10	-	4,5	2	19,6
12	-	6,5	2,9	28,4
14	-	9	3,9	38,3
16	-	11,5	4,9	48,1
18	-	14,8	6,3	61,8
20	-	18	7,6	74,5
22	-	22	9,2	90,2
24	3	26	10,5	103
26	-	30,5	12,6	124

Linear weight of a polyester rope of diameter 20 mm

Nylon and Polyester 3- and 8-strand

Diam. Ø	Circ.	NYLON Mass	NYLON Min. breaking load		POLYESTER Mass	POLYESTER Min. breaking load	
mm	inch "	kg/100m	T	kN	kg/100m	T	kN
6	-	2,25	0,75	7,4	2,7	0,71	7
8	1	4	1,35	13,2	4,8	1,28	12,6
10	1 ¼	6,2	2,08	20,4	7,6	2	19,6
12	1 ½	8,9	3	29,4	11	2,9	28
14	1 ¾	12,2	4,1	40,2	14,8	4	39,2
16	2	15,8	5,3	52	19,5	5,1	50
18	2 ¼	20	6,7	65,7	24,5	6,8	67
20	2 ½	24,5	8,3	81,4	30,3	8,1	79
22	2 ¾	30	10	98	36,7	9,3	91
24	3	35,5	12	118	43,7	11,8	116
26	-	42	14	137	51,2	13,9	136

Linear weight of a combination rope of diameter 16 mm

Combination

6x19 + fibre core galvanized steel wire 1960n/mm² Blue polypropylene cover				6x7 + IWRC (6x19) galvanized steel wire 1960 n/mm² green HSCP cover			
Diam. Ø	Mass	Min. breaking load		Diam. Ø	Mass	Min. breaking load	
mm	kg/100m	T	kN	mm	kg/100m	T	kN
12	22,9	4,5	44,1	12	20	4	39,2
14	28,5	5,4	53,0	14	29	5,5	53,9
16	34,1	6,4	62,8	16	37	7,3	71,6
18	39,4	7,2	70,6	18	43	8,5	83,4
20	49,8	8,6	84,3	20	55	10,8	106
22	58,8	9,7	95,1	22	64	12,6	124
24	69,5	11,2	110	24	83	16,6	163
26	79	12,8	126	26	93	17,9	176

- CALCULATIONS OF ROPES LENGTHS

A first calculation is performed with selected data

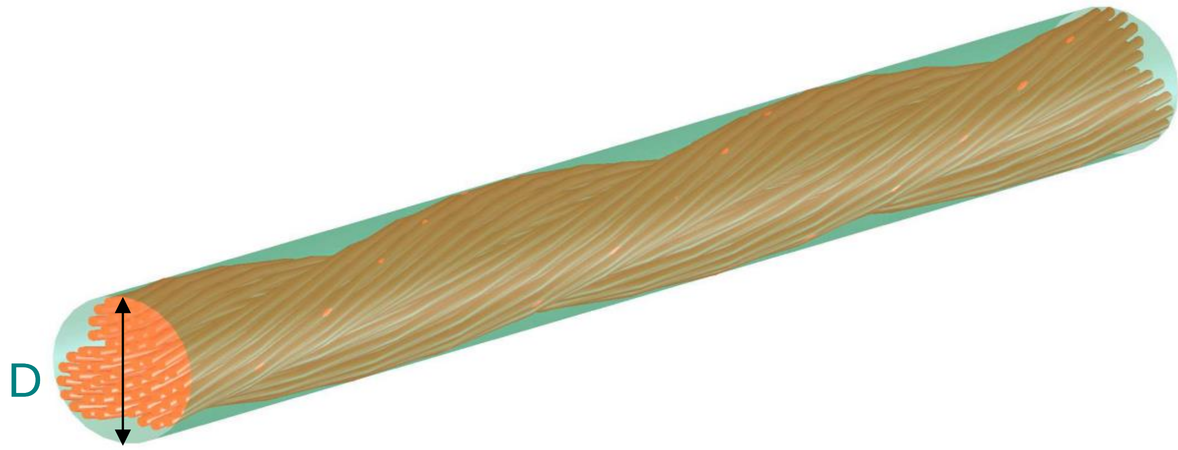
			key	formulas
1				
FAD SETUP DEPTH	(m)	1100	D	
2				
TOTAL BUOY ROPE LENGTH	(m)	1540	TL	TL=D*r
3				
WATER DENSITY		1.025	dsea	
4				
EXCESS LENGTH RATIO		1.4	r	
(Relation between the length of the buoy rope and the depth)				
(usually between 1.3 and 2				
5				
LOOP TOP DEPTH	(m)	250	ltd	
(without current)				
6				
LOOP LENGTH	(m)	440		= TL-D
LOOP ARM LENGTH	(m)	220	Ll	= (TL-D)/2
7				
ROPE CHARACTERISTICS				
A. FLOATING ROPE				
Weight in air for 100 m	(kg)	18	Waf	
Relative density		0.92	dMf	
B. SINKING ROPE				
Weight in air for 100 m	(kg)	30.3	Was	
Relative density		1.38	dMs	
7				
WEIGHT IN WATER OF ONE METER OF FLOATING ROPE	(kg)	-0.02054	Wwf	= (Waf*(1-(dsea/dMf)))/100
WEIGHT IN WATER OF ONE METER OF SINKING ROPE	(kg)	0.077946	Wws	= (Was*(1-(dsea/dMs)))/100
8				
DISTRIBUTION OF THE ROPES IN THE LOOP ARM				
LENGHT OF FLOATING ROPE IN TH LOOP ARM	(m)	174.1	Lf	= Ll*(Wws/(-Wwf+Wws)) because we have : - Lf*Wwf = Ls*Wws et Lf+Ls = Ll
LENGHT OF SINKING ROPE IN THE LOOP ARM	(m)	45.9	Ls	= Ll*(-Wwf/(-Wwf+Wws)) (in the loop arm, the buoyancy of the floating rope equals the weight in water of the sinking rope)
9				
TOTAL LENGTH OF FLOATING ROPE	**(m)**	1024		= D-ltd+Lf
TOTAL LENGTH OF SINKING ROPE	**(m)**	516		= ltd+Ll+Ls

By slightly decreasing the ratio and adjusting the depth of the loop, we can round the lengths of rope, which is more convenient for the purchase of the coils of rope and the FAD making.

			key	formulas
1				
FAD SETUP DEPTH	(m)	1100	D	
2				
TOTAL BUOY ROPE LENGTH	(m)	1500.4	TL	TL=D*r
3				
WATER DENSITY		1.025	dsea	
4				
EXCESS LENGTH RATIO		1.364	r	
(Relation between the length of the buoy rope and the depth)				
(usually between 1.3 and 2				
5				
LOOP TOP DEPTH	(m)	258	ltd	
(without current)				
6				
LOOP LENGTH	(m)	400.4		= TL-D
LOOP ARM LENGTH	(m)	200.2	Ll	= (TL-D)/2
7				
ROPE CHARACTERISTICS				
A. FLOATING ROPE				
Weight in air for 100 m	(kg)	18	Waf	
Relative density		0.92	dMf	
B. SINKING ROPE				
Weight in air for 100 m	(kg)	30.3	Was	
Relative density		1.38	dMs	
7				
WEIGHT IN WATER OF ONE METER OF FLOATING ROPE	(kg)	-0.02054	Wwf	= (Waf*(1-(dsea/dMf)))/100
WEIGHT IN WATER OF ONE METER OF SINKING ROPE	(kg)	0.077946	Wws	= (Was*(1-(dsea/dMs)))/100
8				
DISTRIBUTION OF THE ROPES IN THE LOOP ARM				
LENGHT OF FLOATING ROPE IN TH LOOP ARM	(m)	158.4	Lf	= Ll*(Wws/(-Wwf+Wws)) because we have : - Lf*Wwf = Ls*Wws et Lf+Ls = Ll
LENGHT OF SINKING ROPE IN THE LOOP ARM	(m)	41.8	Ls	= Ll*(-Wwf/(-Wwf+Wws)) (in the loop arm, the buoyancy of the floating rope equals the weight in water of the sinking rope)
9				
TOTAL LENGTH OF FLOATING ROPE	**(m)**	1000		= D-ltd+Lf
TOTAL LENGTH OF SINKING ROPE	**(m)**	500		= ltd+Ll+Ls

- CALCULATION OF THE ROPE DENSITY

The ropes used in FAD mooring lines are neither homogeneous nor cylindrical; part of their apparent volume is composed of water when they are immersed.
To simplify and do the modeling calculation, we assimilate them to fictitious cylindrical and homogeneous ropes. The value of the density of those fictitious ropes is determined so that their weight in water is the same as that of the real ropes. That density will be used in the calculation of the length of the ropes.
The linear mass of the ropes, necessary for the calculation of the density, is often given by the manufacturer. If not, you can get it by weighing a sample and converting the data in kg/100m.



Real rope (in orange) and equivalent fictitious rope (in green)

CALCUL FOR POLYPROPYLENE ROPE

m linear mass of the rope
M *density of the material of the rope*
D *diameter of the equivalent rope*
ρ *density of sea water*
The real rope and the equivalent rope have the same weight in water:

$m(1-\rho/M)=M'V(1-\rho/M')$

The volume of the equivalent rope is:

$V=PiD^2/4$

The density of the equivalent rope is:

$$M'=(m+\rho((PiD^2/4)-((m/M)))/(PiD^2/4)$$

value		numerical value	unit
m	linear mass of the rope	18	kg/100 m
M	density of the material of the rope	0.92	t/m^3
D	diameter of the equivalent rope	20	mm
ρ	density of sea water	1.025	t/m^3

M'	density of the equivalent rope	959.6	kg/m^3

CALCUL FOR POLYESTER ROPE

value		numerical value	unit
m	linear mass of the rope	30.3	kg/100 m
M	density of the material of the rope	1.38	t/m^3
D	diameter of the equivalent rope	20	mm
ρ	density of sea water	1.025	t/m^3

M'	density of the equivalent rope	1273.1	kg/m^3

CALCUL FOR COMBINATION ROPE

The 34.1 kg/100m are divided into 24 kg/100m of steel and 10.1 kg/100m of polypropylene

The density of the rope equivalent to a mixed rope is given by the formula:

$$M'=(m_1+m_2+\rho((PiD^2/4)-((m_1/M_1)+(m_2/M_2)))/(PiD^2/4)$$

value		numerical value	unit
m_1	linear mass of material 1 in the rope	10.1	kg/100 m
M_1	density of material 1	0.92	t/m^3
m_2	linear mass of material 2 in the rope	24	kg/100 m
M_2	density of material 2	7.8	t/m^3
D	diameter of the equivalent rope	16	mm
ρ	density of sea water	1.025	t/m^3

M'	density of equivalent rope	2004.5	kg/m^3

- FAD CALCULATIONS CARD

CONDOR FAD CHARACTERISTICS AND CALCULATIONS CARD

FAD Characteristics
Depht: 1100 m
Total lenght of anchor line: 1500 m
and 23 m of string
Ratio: 1.36
Watch circle: 1093 m
Top of the loop depht: 258 m

Floats Characteristics

float	*nom*	*quantity*	*type*	*dimensions*	*weight*	*volume*	*buoyancy*
type1	FLOAT	46	sphere	radius: 0.1385 m	2.62 kg	11 dm3	8 liters
type2	FLAG	1	sphere	radius: 0.25 m	32 kg	65 dm3	33 liters

Total volume of floats: 576 dm3
Total weight of floats: 153 kg
Total buoyancy of floats: 423 litres

Ropes characteristics

rope	*name*	*quantity*	*density*	*diameter*	*length*	*weight*	*apparent weight*
type 1	PP20	1	959.6 kg/m3	20 mm	1000 m	180 kg	-21 kg
type 2	PES20	1	1273.1 kg/m3	20 mm	300 m	91 kg	23 kg
type 3	COMBINATION16	1	2004.5 kg/m3	16 mm	200 m	68 kg	39 kg
type 4	INTER20	46	2004.5 kg/m3	20 mm	0.5 m	0.28 kg	0.15 kg

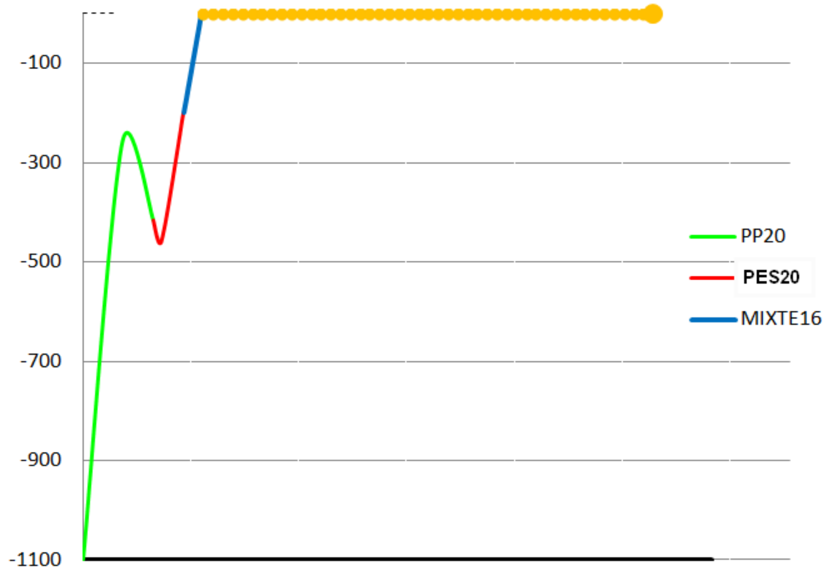
Total volume of ropes: 456 dm3
Total weight of ropes: 352 kg

Total apparent weight: -388.138 kg

Anchor characteristics

one concrete block, weight 971 kg
safety coefficient: 1.4

- FAD DIAGRAM



- MODELING OF THE FAD WITH THE IFREMER "DCP" SOFTWARE

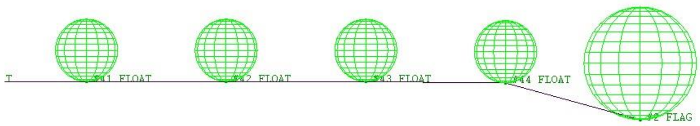
In the "DCP" software:
The "knots" model the floats and the ballasts.
The "elements "model the ropes

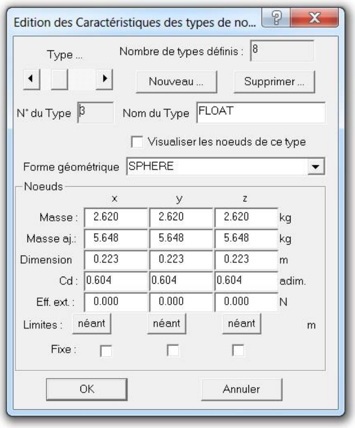
We have 4 types of "knots":
1 CONCRETE BLOCK
46 FLOAT
1 FLAG (flag buoy)
2 LINK (between ropes)

And 4 types of "elements"
46 INTER ropes (between the floats)
1 COMBINATION rope
1 PES20 rope (polyester)
1 PP20 rope (polypropylene or copolymer)

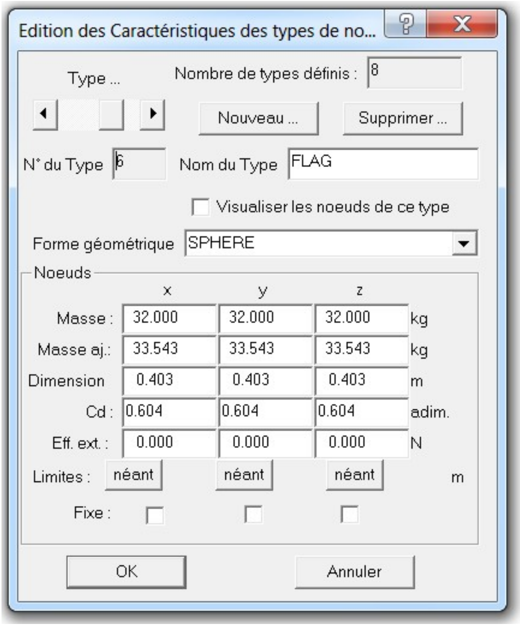
- "KNOTS" AND "ELEMENTS" DEFINITIONS

- FLOAT

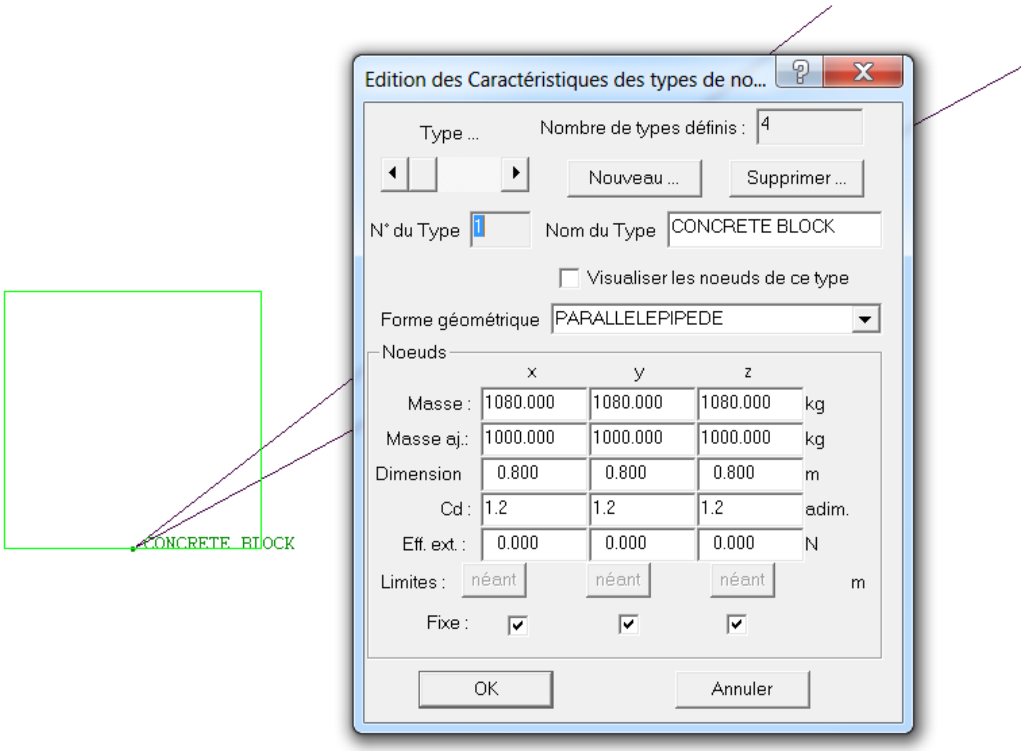




- FLAG

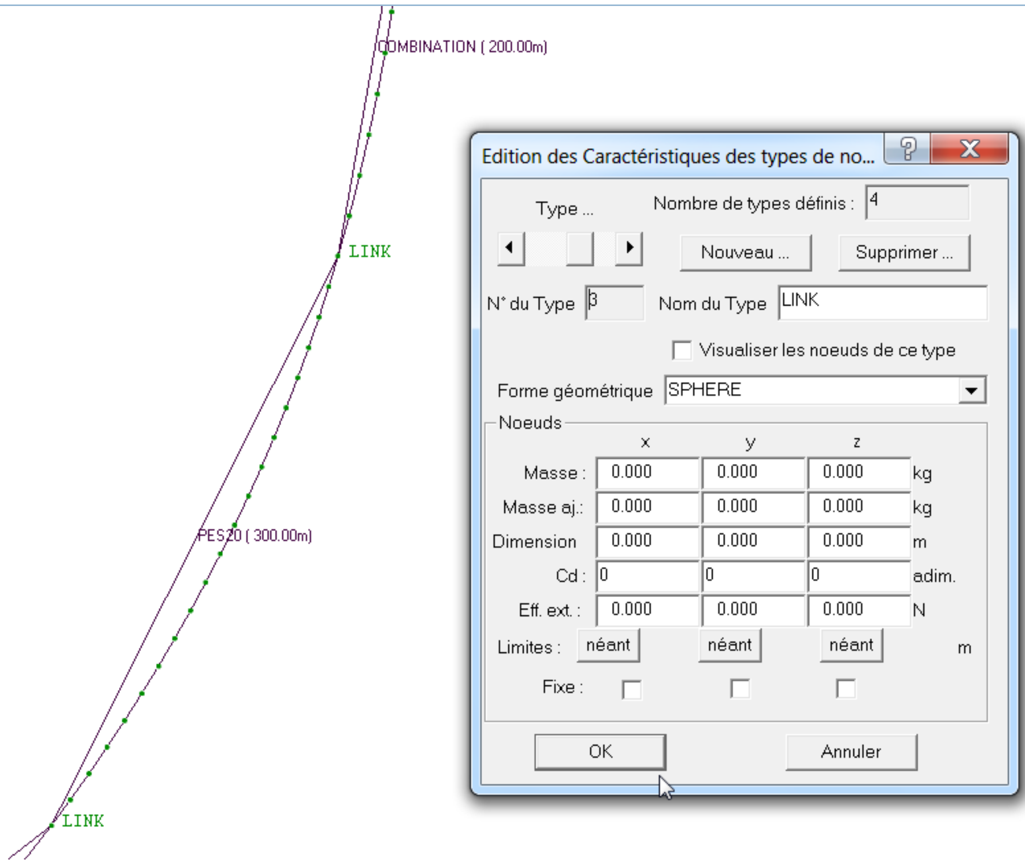


- CONCRETE BLOCK

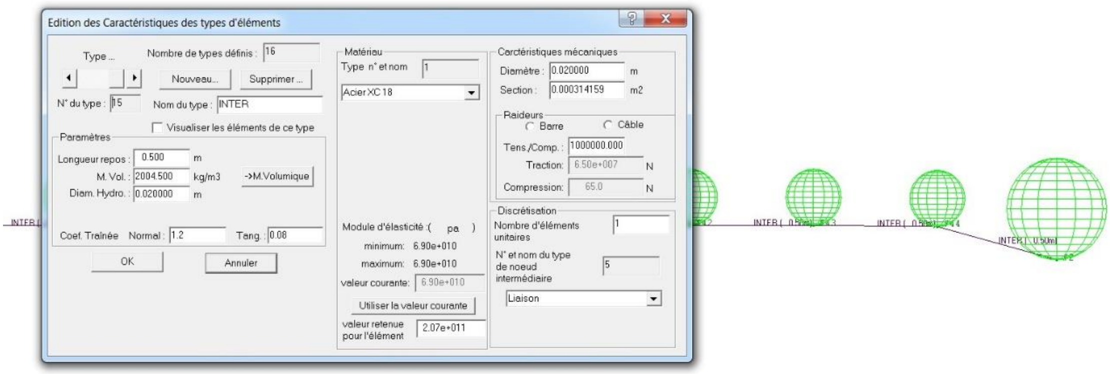


-

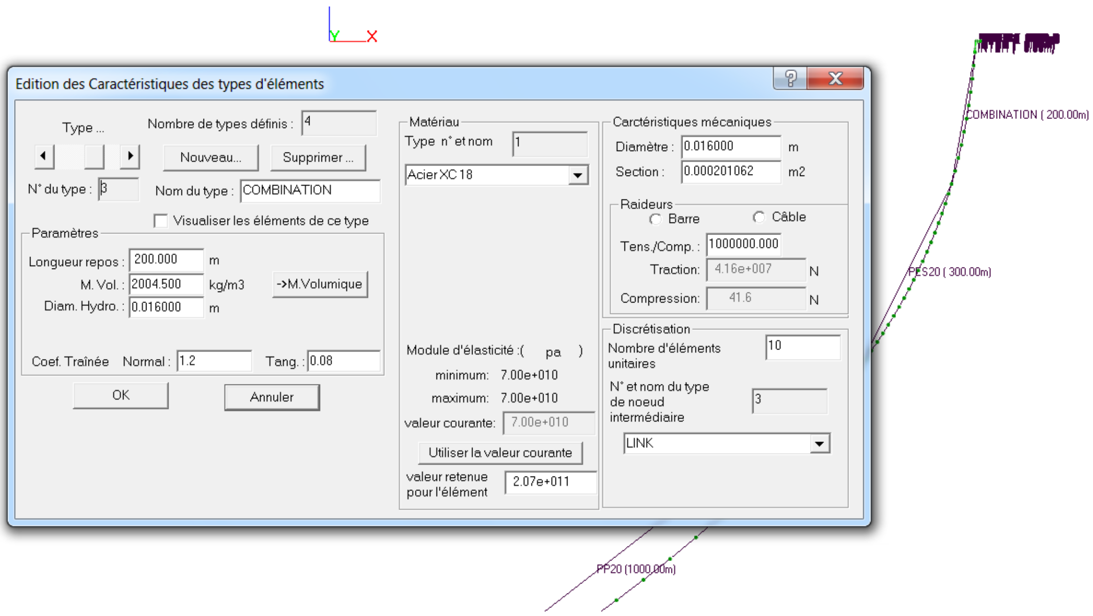
LINK


COMBINATION (200.00m)
LINK
PES20 (300.00m)
LINK
Edition des Caractéristiques des types de no...
Type ...
Nombre de types définis : 4
Nouveau ...
Supprimer ...
N° du Type 3
Nom du Type LINK
Visualiser les noeuds de ce type
Forme géométrique SPHERE
Noeuds
x y z
Masse : 0.000 0.000 0.000 kg
Masse aj.: 0.000 0.000 0.000 kg
Dimension 0.000 0.000 0.000 m
Cd : 0 0 0 adim.
Eff. ext. : 0.000 0.000 0.000 N
Limites : néant néant néant m
Fixe :
OK
Annuler

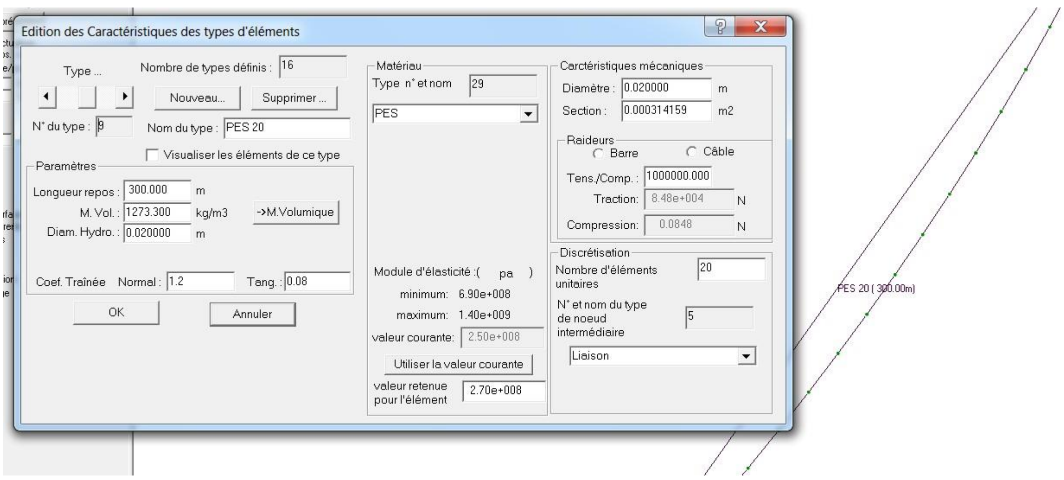
- INTER


Edition des Caractéristiques des types d'éléments
Type ...
Nombre de types définis : 16
Nouveau...
Supprimer ...
N° du type : 15
Nom du type : INTER
Visualiser les éléments de ce type
Paramètres
Longueur repos : 0.500 m
M. Vol. : 2004.500 kg/m3
->M.Volumique
Diam. Hydro. : 0.020000 m
Coef. Traînée Normal : 1.2 Tang. : 0.08
OK
Annuler
Matériau
Type n° et nom 1
Acier XC 18
Module d'élasticité :(pa)
minimum: 6.90e+010
maximum: 6.90e+010
valeur courante: 6.90e+010
Utiliser la valeur courante
valeur retenue pour l'élément 2.07e+011
Carctéristiques mécaniques
Diamètre : 0.020000 m
Section : 0.000314159 m2
Raideurs
Barre
Câble
Tens./Comp. : 1000000.000
Traction: 6.50e+007 N
Compression: 65.0 N
Discrétisation
Nombre d'éléments unitaires 1
N° et nom du type de noeud intermédiaire 5
Liaison

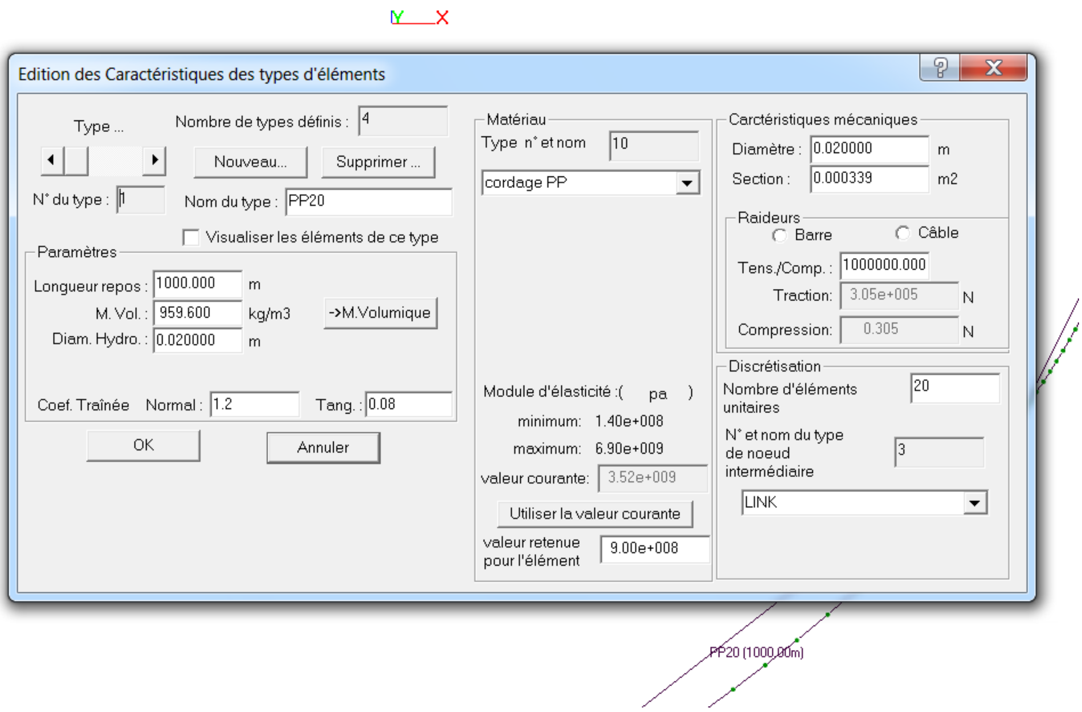
- COMBINATION



- PES20



- PP20



- EXTRACT FROM THE DCP SOFTWARE DESCRIPTION FILE

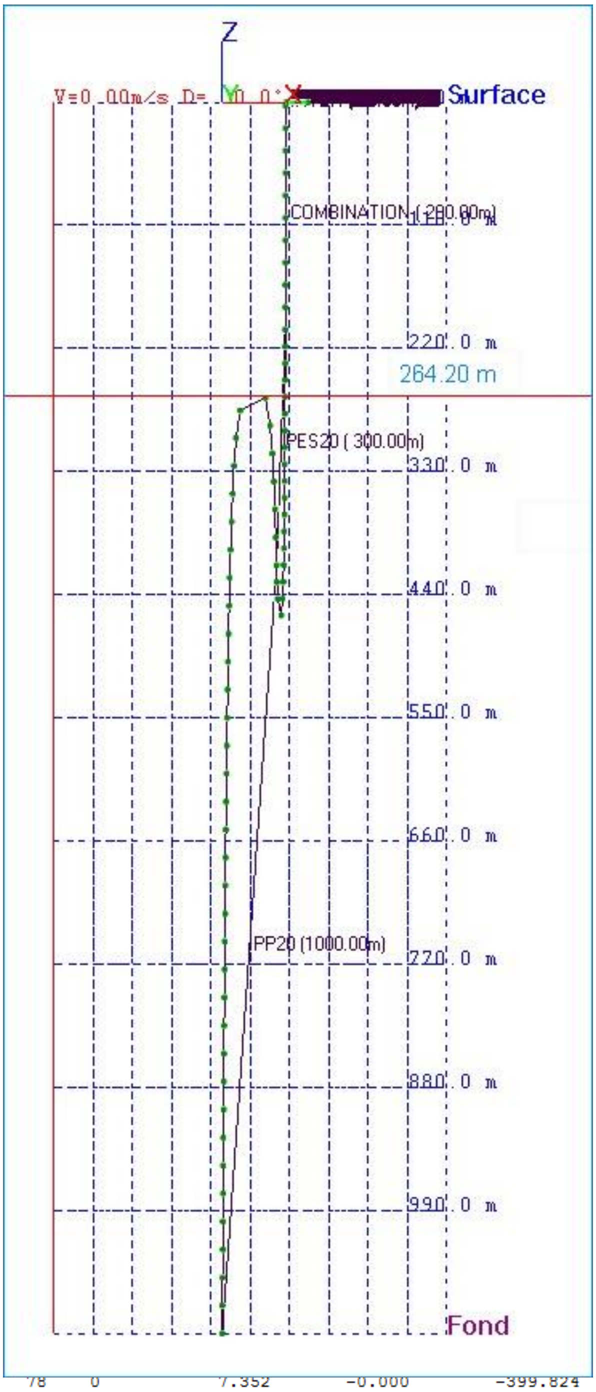
```
            IFREMER - Module DCP - le  27/02/18 - 10:23:53

 Fichier descriptif du DCP ( *.mdf)



  Poids et volume du DCP
               Longueur totale des éléments :            1523.000 m
               Poids total des éléments :                 516.544 kg
               Volume total des éléments :                  0.456 m3
               Poids total des noeuds libres :            152.520 kg
               Volume total des noeuds :                    0.576 m3
               Flottabilité totale :                    10367.604 N
               Poids total :                              669.064 kg
               Poids apparent total :                     388.138 kg
```

```
          LISTE DES TYPES DE NOEUDS
Nombre de Types :                                         4
    N° du type :                                             1
    Nom du type :                                                CONCRETE BLOCK
              Masses X,Y,Z :                                1080.000  1080.000        1080.000 kg
              Masses ajoutées X,Y,Z :                       1000.000  1000.000        1000.000 kg
              Longueurs X,Y,Z :                                0.500     0.500           1.000 m
              Coef. traînée X,Y,Z :                            1.200     1.200           1.200 adim.
              Efforts extérieurs X,Y,Z :                       0.000     0.000           0.000 N
              Déplacement X,Y,Z :                                  1         1               1 adim.
              Limites X,Y,Z :                                 99.000    99.000          99.000 m
              Sens des limites X,Y,Z :                             0         0               0 adim.

    N° du type :                                             2
    Nom du type :                                                          FLAG
              Masses X,Y,Z :                                  32.000    32.000          32.000 kg
              Masses ajoutées X,Y,Z :                         33.543    33.543          33.543 kg
              Longueurs X,Y,Z :                                0.403     0.403           0.403 m
              Coef. traînée X,Y,Z :                            0.604     0.604           0.604 adim.
              Efforts extérieurs X,Y,Z :                       0.000     0.000           0.000 N
              Déplacement X,Y,Z :                                  0         0               0 adim.
              Limites X,Y,Z :                                  0.000     0.000           0.000 m
              Sens des limites X,Y,Z :                             0         0               0 adim.

    N° du type :                                             3
    Nom du type :                                                          LINK
              Masses X,Y,Z :                                   0.000     0.000           0.000 kg
              Masses ajoutées X,Y,Z :                          0.000     0.000           0.000 kg
              Longueurs X,Y,Z :                                0.000     0.000           0.000 m
              Coef. traînée X,Y,Z :                            0.000     0.000           0.000 adim.
              Efforts extérieurs X,Y,Z :                       0.000     0.000           0.000 N
              Déplacement X,Y,Z :                                  0         0               0 adim.
              Limites X,Y,Z :                                  0.000     0.000           0.000 m
              Sens des limites X,Y,Z :                             0         0               0 adim.

    N° du type :                                             4
    Nom du type :                                                         FLOAT
              Masses X,Y,Z :                                   2.620     2.620           2.620 kg
              Masses ajoutées X,Y,Z :                          5.703     5.703           5.703 kg
              Longueurs X,Y,Z :                                0.223     0.223           0.223 m
              Coef. traînée X,Y,Z :                            0.604     0.604           0.604 adim.
              Efforts extérieurs X,Y,Z :                       0.000     0.000           0.000 N
              Déplacement X,Y,Z :                                  0         0               0 adim.
              Limites X,Y,Z :                                  0.000     0.000           0.000 m
              Sens des limites X,Y,Z :                             0         0               0 adim.
```

```
          LISTE DES TYPES D'ELEMENTS
Nombre de Types :                                      4
    N° du type :                                        1
    Nom du type :                                                      PP20
              Module d'élasticité:                    900000000.000 N
              Raideur traction:                       305000.000 N
              Raideur compression:                         0.305 N
              Longueur au repos :                       1000.000 m
              N° et nom du matériau :                   10 cordage PP
              Diamètre mécanique :                         0.020 m
              Traction/Compression :                  1000000.000 adim.
              Masse volumique :                          959.600 kg/m3
              Diamètre hydrodynamique :                    0.020 m
              Cd normal :                                  1.200 adim.
              Cd tangentiel :                              0.080 adim.
              Nombre de barres (discrétisation:       20
              N° du Type de noeud intermédiaire:        3

    N° du type :                                        2
    Nom du type :                                                     PES20
              Module d'élasticité:                    270000000.000 N
              Raideur traction:                        91500.000 N
              Raideur compression:                         0.091 N
              Longueur au repos :                        300.000 m
              N° et nom du matériau :                   29 PES
              Diamètre mécanique :                         0.020 m
              Traction/Compression :                  1000000.000 adim.
              Masse volumique :                         1273.100 kg/m3
              Diamètre hydrodynamique :                    0.020 m
              Cd normal :                                  1.200 adim.
              Cd tangentiel :                              0.080 adim.
              Nombre de barres (discrétisation:       20
              N° du Type de noeud intermédiaire:        3

    N° du type :                                        3
    Nom du type :                                               COMBINATION
              Module d'élasticité:                    207000000000.000 N
              Raideur traction:                       41600000.000 N
              Raideur compression:                        41.600 N
              Longueur au repos :                        200.000 m
              N° et nom du matériau :                    1 Acier XC 18
              Diamètre mécanique :                         0.016 m
              Traction/Compression :                  1000000.000 adim.
              Masse volumique :                         2004.500 kg/m3
              Diamètre hydrodynamique :                    0.016 m
              Cd normal :                                  1.200 adim.
              Cd tangentiel :                              0.080 adim.
              Nombre de barres (discrétisation:       10
              N° du Type de noeud intermédiaire:        3

N° du type :                                  4
Nom du type :                                                  INTER
          Module d'élasticité:                207000000000.000 N
          Raideur traction:                   65000000.000 N
          Raideur compression:                      65.000 N
          Longueur au repos :                        0.500 m
          N° et nom du matériau :                  1 Acier XC 18
          Diamètre mécanique :                       0.020 m
          Traction/Compression :              1000000.000 adim.
          Masse volumique :                     2004.500 kg/m3
          Diamètre hydrodynamique :                  0.020 m
          Cd normal :                                1.200 adim.
          Cd tangentiel :                            0.080 adim.
          Nombre de barres (discrétisation:   1
          N° du Type de noeud intermédiaire:  3
```

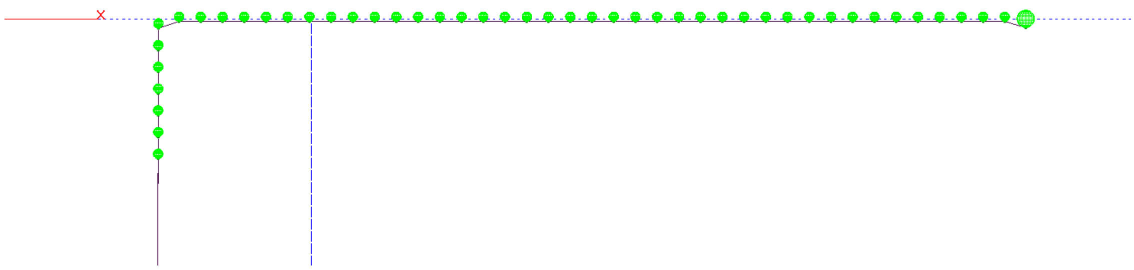
The total apparent weight (388.18 kg) returned by the result file of the software is the same as that obtained by the preparatory calculations, which confirms that no error occurred during the description of the elements of the FAD in the software.

- FAD MODELING WITH ZERO CURRENT



78	0	7.352	-0.000	-399.824	-0.00	0.00	-5.03
79	0	8.145	-0.000	-374.834	-0.00	0.00	-5.03
80	0	9.129	-0.000	-349.852	-0.00	0.00	-5.03
81	0	10.428	-0.000	-324.885	-0.00	0.00	-5.03
82	0	12.341	-0.000	-299.957	-0.00	0.00	-5.04
83	0	15.986	-0.000	-275.224	-0.00	0.00	-5.04
84	0	38.434	-0.001	-264.220	-0.00	0.00	-5.04
85	0	42.626	-0.001	-288.866	-0.01	0.00	-5.04
86	0	44.645	-0.001	-313.785	-0.01	0.00	-5.03
87	0	45.965	-0.001	-338.752	-0.01	0.00	-5.03

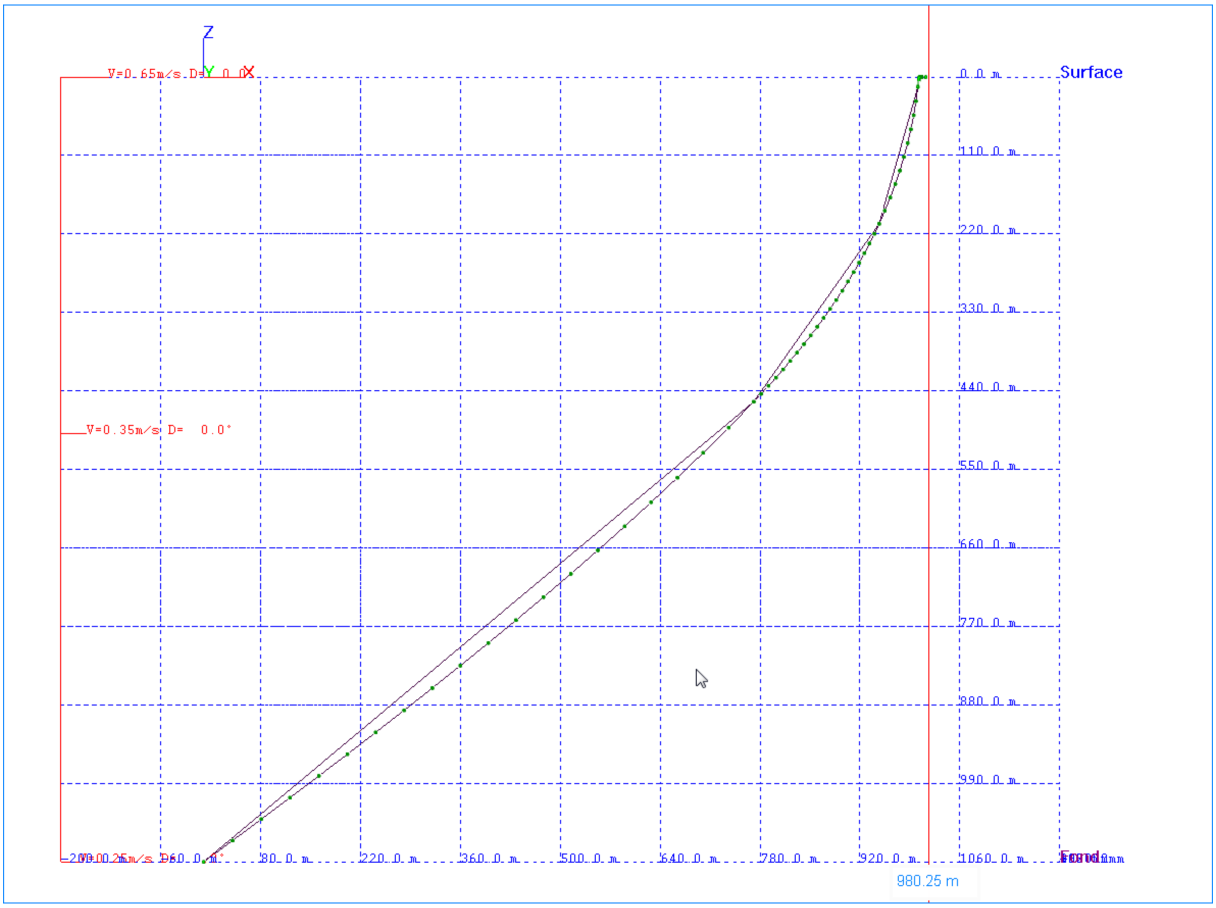
The depth of the loop found on the model (264 m) is very close to that provided by the preparatory calculations (258 m)



Head of the FAD with zero current
Seven floats are sunk by the weight of the mixed and polyester ropes

- FAD MODELING WITH MAXIMUM THEORITICAL CURRENT

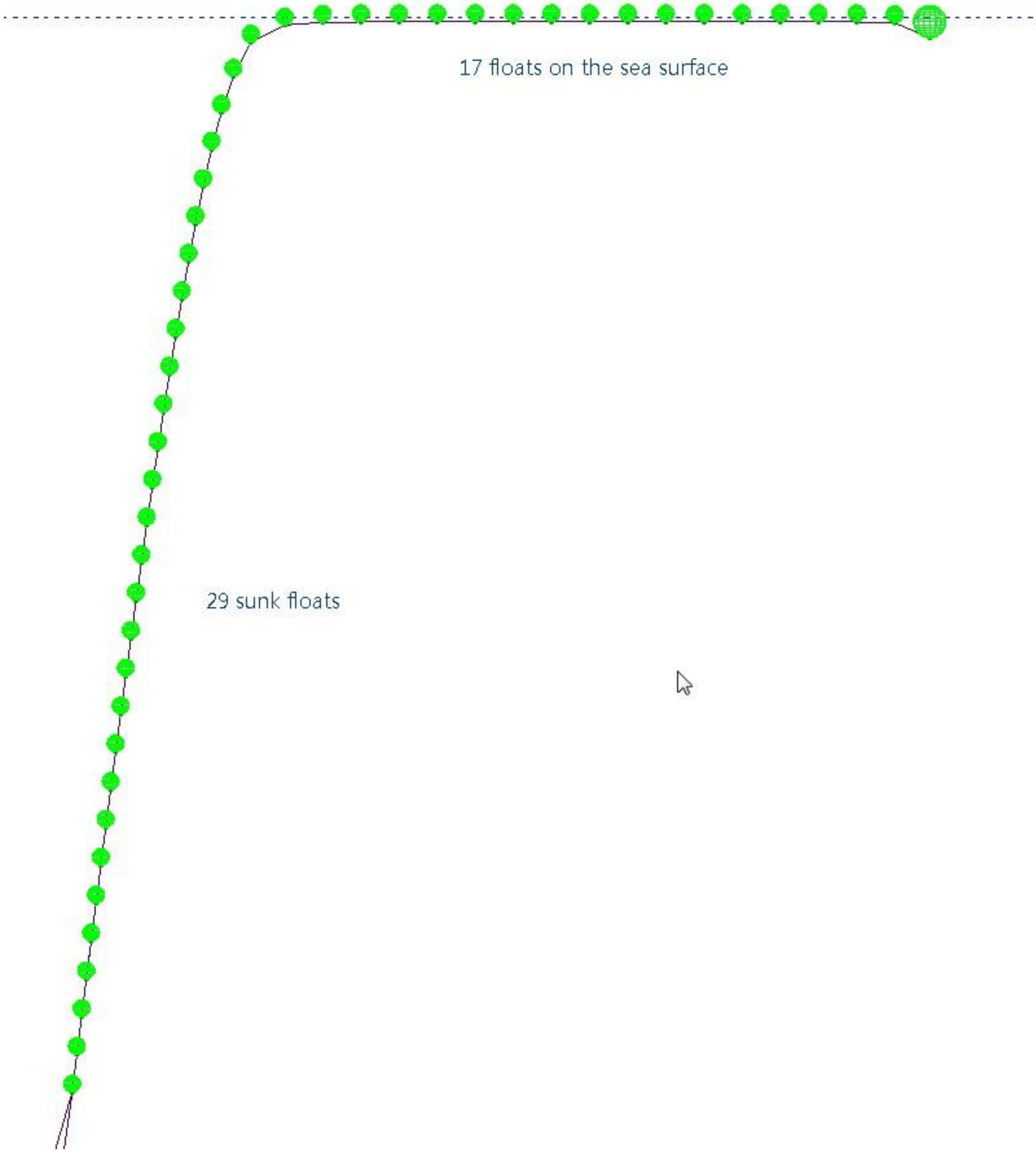
Depht(m)	Current velocity (m/s)
0	0.65
500	0.35
1100	0.25



Nombre de noeuds : 50

Coordonnées en m

N°	X	Y	Z	N°du point 3d	N°du type	Nom du type
1	0.000	0.000	-1100.000	1	1	'CONCRETE BLOCK'
2	980.250	-0.040	-0.192	2	2	'FLAG'
3	798.934	0.000	-486.848	2	3	'LINK'
4	938.447	-0.001	-213.300	3	3	'LINK'
5	971.920	-0.003	-16.109	4	4	'FLOAT'
6	971.953	-0.003	-15.610	5	4	'FLOAT'



The FAD safely supports the maximum current, 17 floats and the flag buoy stay on the surface under these conditions.

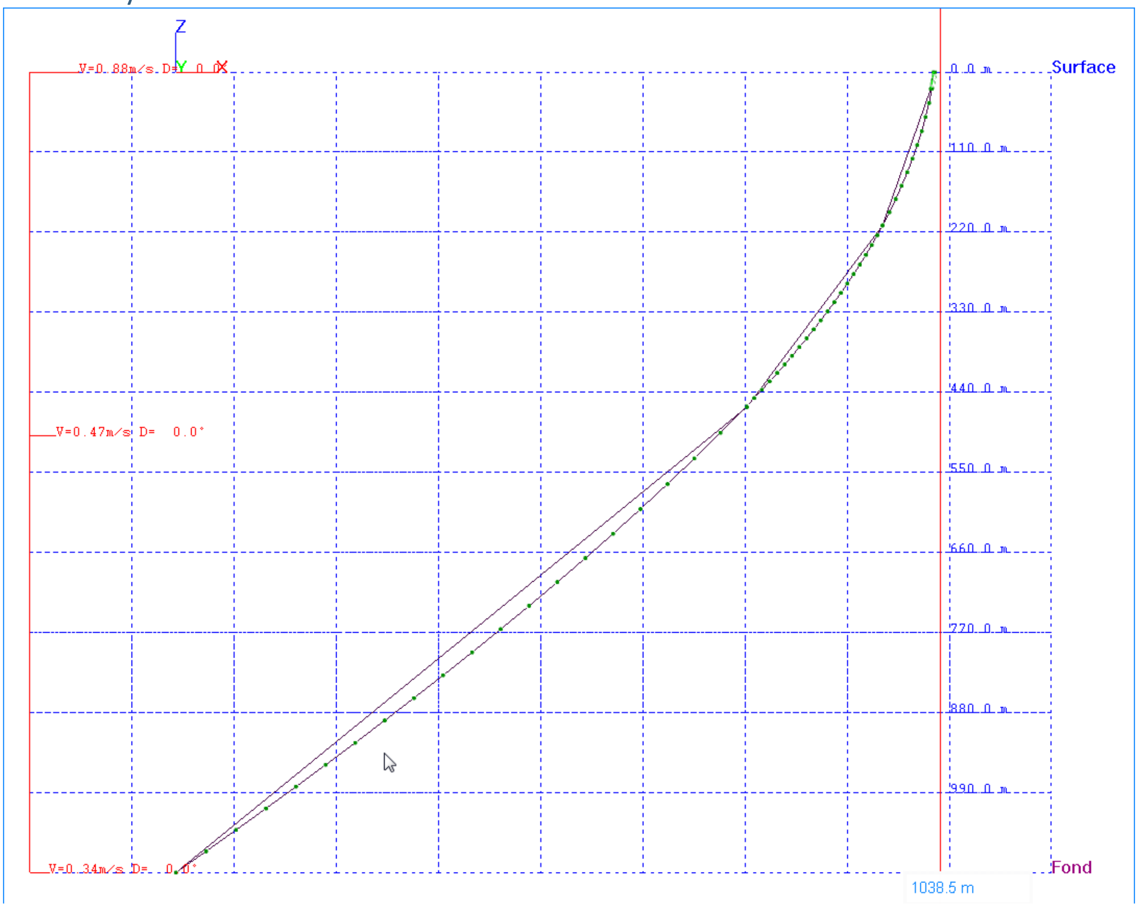
- FAD MODELING WITH A CURRENT CAUSING ITS TOTAL IMMERSION

To evaluate the margin of safety, a stronger current is applied to the FAD until it is totally immersed. This current is normally impossible in the zone.

The total immersion current is defined by the table:

Depht(m)	Current velocity (m/s)
0	0.88
500	0.47
1100	0.34

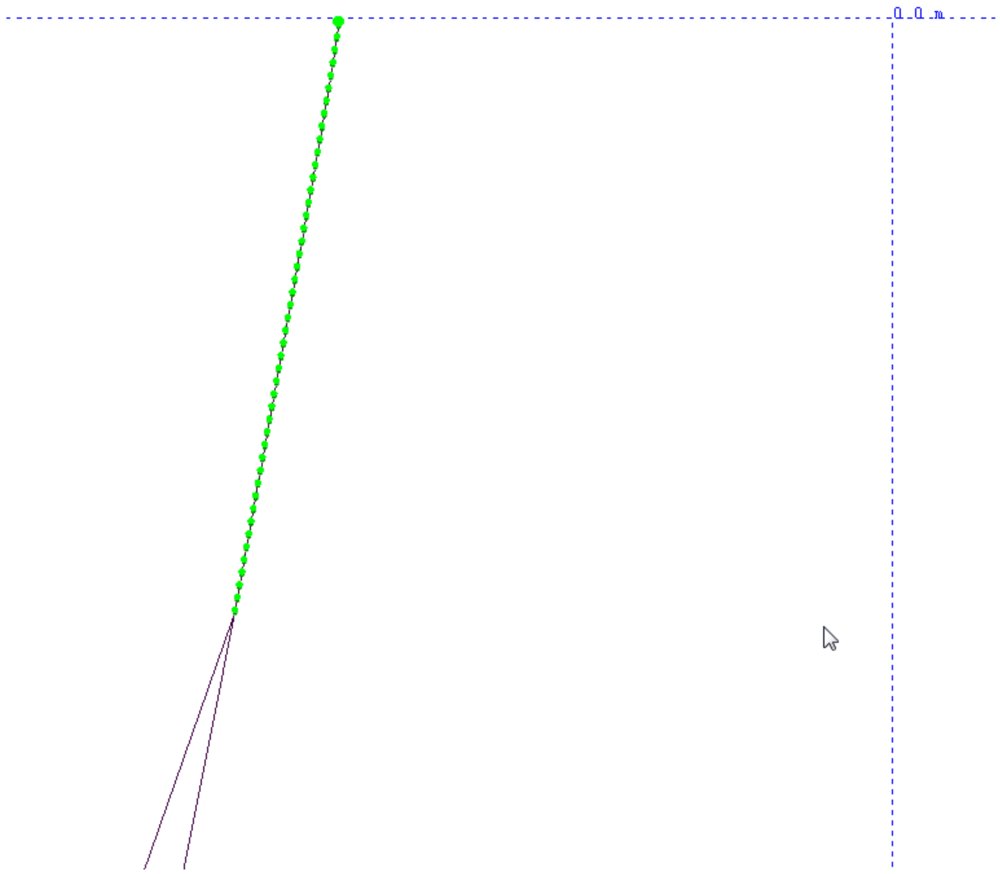
The safety factor relative to the maximum current is 1.35



Nombre de noeuds : 50

Coordonnées en m

N°	X	Y	Z	N°du point 3d	N°du type	Nom du type
1	0.000	0.000	-1100.000	1	1	'CONCRETE BLOCK'
2	1038.596	-0.009	-0.345	2	2	'FLAG'
3	782.543	-0.006	-460.445	2	3	'LINK'
4	968.434	-0.008	-210.963	3	3	'LINK'
5	1034.588	-0.009	-22.994	4	4	'FLOAT'



DCP head with total immersion current

- CALCULATING ANCHOR WEIGHT

The minimum weight of the anchor must be such that its weight in water is the opposite of the weight in water of the FAD (total apparent weight:-338 kg).

This is the maximum weight that the FAD can lift when it is completely submerged. At this minimum weight, a safety coeficient is used to ensure that the anchor can not slide on the bottom.

The following table details the calculation used and gives its result for a concrete anchorage (density of concrete: 2)

PI =(B4/(1-(B1/B2)))*B5

A	B	C
dsea =density of sea water	1.025	
dmat = density of material	2	
Wair = weight in air		
Wwat= weight in water	338	kg
Sc=Safety coefficent	1.4	
Wair = (Wwat/(1-(dsea/dmat)))Sc	971	kg

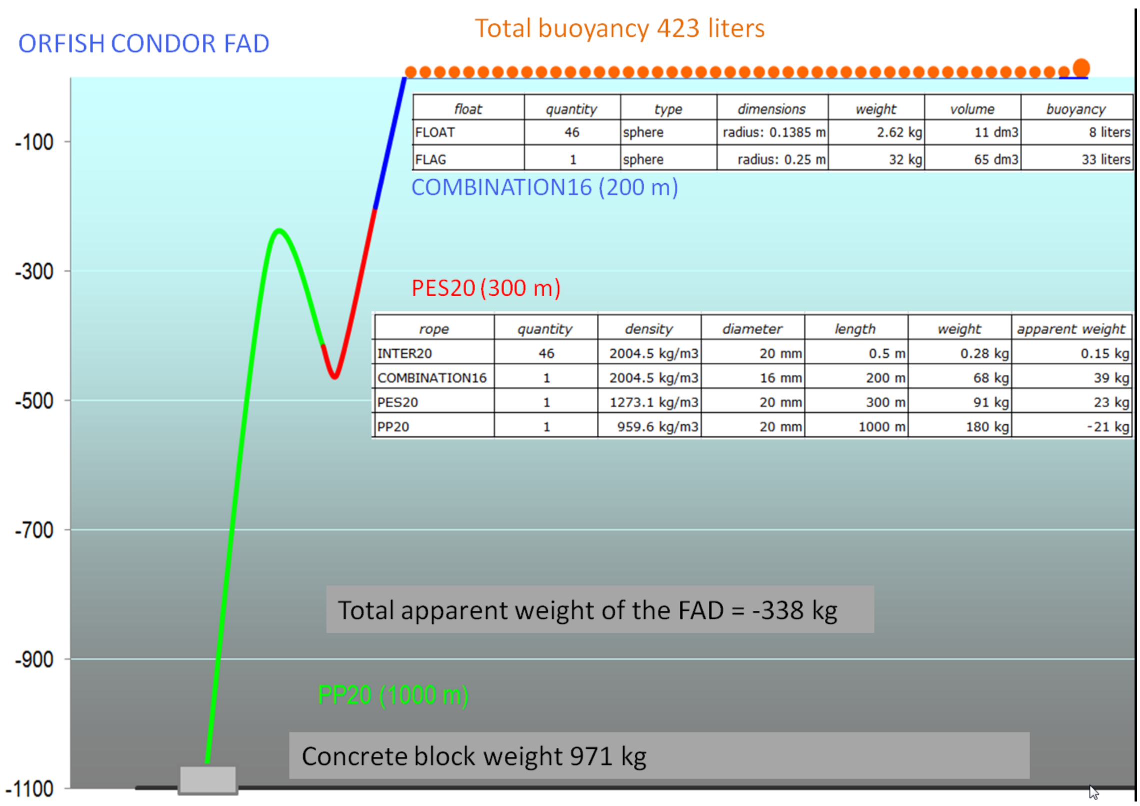
For example, the following table provides the dimensions of a parallelepiped concrete block suitable for the FAD.
The density of the concrete can be greater than 2000 kg / m3 according to the nature of the aggregates used; a weighing of the block is interesting to specify this data.

Lenght	0.80	m
width	0.80	m
height	0.76	m
dmat = density of material	2000	kg/m3
Wair = weight in air	971	kg

- CONCLUSION

The moderate current guided the choices of the main features of the FAD.
Modeling validated these choices. With a buoyancy of 400 liters the FAD can be equipped with an anchor line of 20 mm in diameter and will remain on the surface during the strongest currents envisaged in the zone.
The chosen length ratio (1.36) will generate a moderate watch circle radius of about 1000 m.
A concrete block of about 1 ton is enough to anchor it
By way of comparison to obtain unsinkable FADs in the Caribbean zone; the buoyancy must reach 600 liters for an anchor line diameter of 14 mm and a ratio of 2 which provides watch circle radius of up to 3000 m.
As a result the proposed FAD will suit the region, it can be easily adapted to other installation sites, and support modifications if new constraints are identified (decrease in buoyancy or ratio, for example).

- CONDOR FAD FINAL DIAGRAM



float	quantity	type	dimensions	weight	volume	buoyancy
FLOAT	46	sphere	radius: 0.1385 m	2.62 kg	11 dm3	8 liters
FLAG	1	sphere	radius: 0.25 m	32 kg	65 dm3	33 liters

rope	quantity	density	diameter	length	weight	apparent weight
INTER20	46	2004.5 kg/m3	20 mm	0.5 m	0.28 kg	0.15 kg
COMBINATION16	1	2004.5 kg/m3	16 mm	200 m	68 kg	39 kg
PES20	1	1273.1 kg/m3	20 mm	300 m	91 kg	23 kg
PP20	1	959.6 kg/m3	20 mm	1000 m	180 kg	-21 kg