EURO-ARGO RISE

RESEARCH INFRASTRUCTURE SUSTAINABILITY AND ENHANCEMENT

D2.6 condensed version

FEBRUARY 2, 2022

Euro-Argo ERIC Office
Authored by: Luca Arduini Plaisant

Introduction

The main objective of this deliverable was to issue some recommendations in order to improve Argo floats performances and lifetime through at sea behaviour, life expectancy analyses and metadata reviews. The results of these analyses will be described in this synthetized version of the Deliverable 2.6 that was issued to the European Commission in December 2021.

Most of the observations and conclusions presented hereafter are derived from survival rates analyses and comparisons. The survival rates are a proxy to estimate a sample performance and are systematically computed along three different x-axes: cycles made, age reached (in years) and vertical distance travelled (in Kms)[1].

The Deliverable 2.1, anterior to the D2.6, aimed to propose a methodology for survival rates analyses; from the computation of the survival rate itself, the sample selection, the side effects of a float's configuration on certain axes, etc. The survival rate can be described as the percentage of floats alive at a certain cycle number (or age, or vkms) in the sample:

$$\frac{Floats > x\ cycles}{Floats > x\ cycles + death\ floats < \ x\ cycles}$$

Note that the denominator is not the total of floats deployed but only the floats that were able to reach a certain mark (number of cycles, age or vkms), hence not considering the young alive floats that did not yet reached this mark (but could in the future), that would wrongfully decrease the survival rate of the sample.

Following the D2.1 recommendation, a list of floats dead of battery exhaustion was created, based on some battery level decrease threshold (for Arvor/Provor platform type only). This list permitted to make more detailed analyses on a float model performance and should be extended in the future to other platform types. A float model **performance** can be estimated by its:

- **Efficiency**: Comparing the survival rate of at sea floats dead on battery exhaustion[2] to their theoretical lifetime given by the manufacturers
- **Reliability**: Analyzing the proportion of floats dead on battery exhaustion compared to other causes of death.

At sea survival rates, theoretical lifetimes, proportion of floats dead on battery exhaustion and other metrics are all summarized in the Table 1.

Keep in mind however that a major part of the samples considered hereafter are either very young or containing few dead floats, even less due to battery exhaustion because this study focuses on recently deployed European platform types. These figures will therefore require an update in a few years' time, in order to highlight new performances trends or strengthen observations made in this analysis.

[1] The vertical distance travelled or "vkms" is computed for the descent and ascent of the float. It is the closest proxy to the number of observations (CTD or other sensors points) collected by the floats.

[2] The battery exhaustion of a float is what can be considered as its "natural" death. A float dead of such a cause means that it exploited its maximum potential.

1. Float models' comparisons across Argo missions

1.1 CORE

Survival rates, computed as of September 2021, across Argo CORE float models were examined following the methodology defined in this study (Iridium floats deployed after 2016, removing recovered ones). An example of a survival rates comparison is presented hereafter:

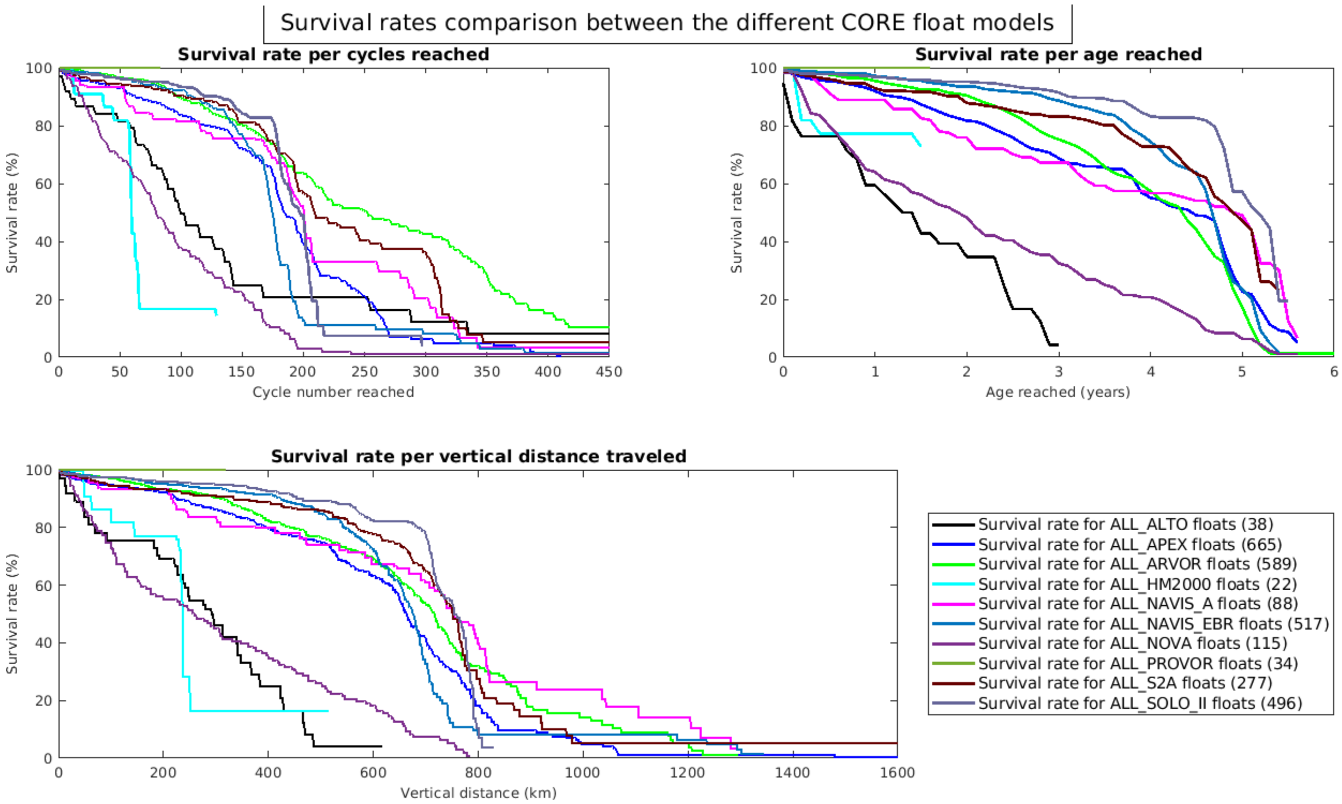

Figure 1 - CORE float models survival rates comparison

Three float models present an overall poor reliability, on each of the x-axes: HM2000, ALTO and NOVA. The rest of the CORE models present rather similar trends. SOLO-II and S2A floats have the best overall survival rates observed at sea, followed by ARVOR, NAVIS and APEX float models.

One can observe the "bump" in the survival rate trend of the ARVOR floats (green curve) in terms of cycles made. This is a side effect of the numerous ARVOR floats deployed in European Marginal Seas with a higher cycling period (generally 5-days or less, compared to the default 10-days cycle period).

1.2 DEEP

Bear in mind that SOLO-D floats operate up to 6000 dbar, and Arvor-D are systematically equipped with a DOXY optode (-15% of the theoretical number of cycles).
- SOLO_D and SOLO_D_MRV clearly account for the best reliability of Deep float models.
- The ARVOR-D and NINJA-D both present a significant number of **early failures**, and a shorter amount of cycles achieved for the floats that worked until battery exhaustion.
- The APEX-D presents the 3rd best reliability in terms of Deep float models. However, when considering non-Japanese floats (that went through a verification process once received at JAMSTEC), they tend to show a lot of early failures, like the ARVOR-D and NINJA-D.

1.3 DOXY sensor integration on Arvor platform type

The manufacturer of the Arvor platform type, NKE, estimated a 15% decrease in terms of cycles made when integrating a DOXY sensor on an ARVOR-I float. This estimation is verified with the floats at sea, with a 14.96% decrease in terms of cycles made (at 50% of the survival rate) for Arvor-I floats equipped with such a sensor, compared to their standard version.

1.4 BGC

It is important to keep in mind that BGC float models have very heterogeneous number of sensors embarked, configurations, sampling rates and even battery pack for certain models (PROVOR CTS5 basic and “JUMBO” version). This BGC array is the latest extension of the Argo program and contains a lot of very young floats. Therefore, for these two main reasons, one should undertake more detailed analyses in order to precisely estimate a BGC float model performance.
However, the following observations can be derived from the survival rates comparisons made:

- **The most reliable model in the BGC array, at the moment, is the PROVOR_III** (NKE CTS4), with a very few premature losses and an important number of cycles, vertical distance and age reached despite a significant number of floats cycling faster than the standard 10-days period.
- APEX-BGC floats, followed by the NAVIS-BGC account for a good survival rate too.
- PROVOR_IV floats survival rate curves were mainly impacted by the proportion (over 40%) of floats deployed in the Arctic Basin. The sample is still young and these Arctic floats does not reflect the overall performances of the model.
- The PROVOR-V float model could not be included in this study since the model has only been deployed very recently, hence not enough floats to analyse.

2. Areas of deployment comparisons

When comparing the survival rates, in age reached (as in OceanOps), the European array present a lower survival rate than the International one. However, when computing the survival rates on the three different x-axes, one can observe that the European array has very similar performances in terms of vkms than the International one. In fact, the numerous floats deployed in Marginal Seas with a shorter cycle time period have three main impacts, observable on each x-axis:

- **Age reached**: A decrease of the survival rate curve (black ellipse **2** in the Figure 2)
- **Cycles made**: An increase of the survival rate curve (ellipse **1**)
- **Vkms**: An early failure trend for some of the floats (ellipse **3**) but a survival rate curve that evens out the International one once past the 600 Vkms travelled (ellipse **4**).

It is undeniable that Marginal Seas deployments induce a proportion of early death failures, that could be explained by a generally harsher environment, proximity to the coast, shallower bathymetry inducing more groundings, etc. However**, for the floats that are living past this early failure trends, their performances even out floats deployed in Open Ocean.**

The direct consequence from these conclusions is that Marginal Seas networks have a shorter refresh time than the Open Ocean ones and deployment teams should increase deployment numbers in order to maintain an operational network in these areas.

3. Configuration parameters and technical behaviour impacts on a float performance

Since the European deployments mainly concern the Arvor platform type, the sample selected focuses on Arvor-I, Arvor-Argos and Arvor-L floats, dead of battery exhaustion, excluding the recovered ones.
The methodology developed through the report permitted to estimate the number of cycles performed for at sea floats dead of battery exhaustion:

- **140 cycles +/- 10 cycles for an Arvor-L**
- **180 cycles +/- 20 cycles for an Arvor-A**
- **230 cycles +/- 10 cycles (*firsts results, young sample*) for an Arvor-I with a standard (Open Ocean) configuration**
- **350 cycles +/- 50 cycles (*firsts results, young sample*) for an Arvor-I with a Marginal Seas configuration**

On the configuration parameters and technical behaviour identified in the D2.1, that could have an impact on Arvor floats lifetime, only a few could have been thoroughly investigated due to the sample selection limit: too few floats were dead after battery exhaustion (**sample still young**), or had enough different values for the considered parameter, or kept the same value for all the float mission.
However, few observations were derived from these analyses:

- The **cycling time period** could be chosen accordingly to the scientific purpose of the float (long term scale analyses: prefer a 10-day cycle period because the float will last more time at sea; prefer a 5-day profile if the objective is to gather as many profiles as possible). However, bear in mind that cycling twice as fast does not result in twice the number of cycles made nor half the age reached.

- The **pressure target tolerance** for stabilization and during the drift are two critical parameters that should not be changed to lower values than, respectively, 30 and 50 dbar. Otherwise, it will induce additional repositioning and battery consumption.

- From an energetic stand point, the first analyses reflect that **groundings** of an Arvor float seem not to affect negatively its energetic consumption. In fact, a float experiencing a grounding will, in most of the cases[3], reach a maximum pressure lower than during a normal profile. Its hydraulic actions will therefore be less costly and the amount of data collected will be smaller, also helping to reduce the energetic consumption during transmission.

[3] The only case where a grounded float will not automatically signify a lower maximum pressure is when a float grounds during a descent to park. With a "CONFIG_GroundingMode" = 0 it will shift upward and try diving again to reach its profile pressure. If it manages to do so without grounding again, it will reach a maximum pressure equivalent to the one reached during a normal cycle.

However, the repetition of groundings could damage the float in the long term. A significant part of European floats experienced **early death failures**, that might be induced by repeated groundings (loss of ballast and bottom hull, etc.).
These analyses should be done again in a couple of years, when more Arvor-I floats will be dead of battery exhaustion. Some of them deployed on the Mediterranean basins will help to derive interesting observations for some of the technical behaviour listed here.

Conclusion

With the tools and methodology developed in this task throughout the duration of the project, Argo floats lifetimes and performances have been extensively investigated. Comparisons between models, deployment basins, Euro-Argo and International arrays have been performed. Observed at sea lifetimes, including for floats having exhausted their batteries, were compared to theoretical lifetimes provided by manufacturers or obtained from workshop presentations or reports. All these key figures have been summarized in the Table 1, but will need to be updated as the Argo fleet become older and more floats will die of battery exhaustion.

We aim to investigate further the case of groundings, as a possible impact on early deaths failures, and for the case of battery exhaustion looking more closely at the different cycle phases where the floats grounded.

Case studies such as in the Baltic or Mediterranean Seas will be further extended to infer best practices for float deployments and recoveries in these areas.

All the work carried out in task 2.6 strongly relied on good metadata filled both at OceanOPS website and in the Argo netCDF on the GDAC. Audits permitted to detect issued that are now corrected. Checks for inconsistencies or missing metadata will be performed.

Eventually, float lifetimes and performances will be continuously monitored, and enhancement of OceanOPS tools and metrics will enable the tracking and use of key metadata (recovered floats, ending causes) and configuration or technical parameter.

ANNEX 1 - Summary table of float's performances across Argo Missions

	Model	Theoretical lifetime (@10 days / 2000m profile depth) (@5 days / alternating 700/2000m)	Average number of cycles for the sample / median	Dead floats	Averaged at sea lifetime for dead floats	% of floats dead on battery (compared to all the dead floats)[4]	Averaged lifetime for floats dead on battery level / median	% of alive floats in the sample	Performance on target score[5]
CORE	Arvor-I (504/86 floats)	270 cycles	104 cycles / 90	51	151 cycles	31%	245 / 221	90%	32%
		480 cycles	213 cycles	24	226 cycles	33%	408 / 340	75%	3.6%
	Arvor-I DO (24/15 floats)	230 cycles	33 cycles / 22	2	32 cycles	0%		87%	37.5%
		400 cycles	131 cycles / 133	3	131 cycles	0%		80%	0%
	Arvor – Argos (425 floats)[6]	231 cycles	141 cycles / 161	328	152 cycles	67%	176 / 176	24%	2%
	Arvor – L (598 floats)[6]	190 cycles	136 / 142	498	137 cycles	68%	141 / 139	17%	8%
	APEX (710 floats)	250 cycles	113 cycles / 108	182	134 cycles	x		74%	?
	NAVIS-A (88 floats)	300 cycles	123 cycles	28	164 cycles	x		67%	21%
	NAVIS-EBR (518 floats)	300 cycles	104 cycles	62	126 cycles	x		87%	8%
	SOLO-II (498 floats)	?	112 cycles	27	51 cycles	x		95%	?

[4] The percentage of floats dead of battery exhaustion is compared to the number of dead floats. Also, since the battery exhausted floats comes from an extract on the CORIOLIS DAC, all the floats outside of this DAC are not considered in this metric. [Dead Arvor-Argos on CORIOLIS DAC = 285 floats; Arvor_L = 173]

[5] The performances on target score is the survival rate % at the theoretical life expectancy given by the manufacturer

[6] The Arvor-Argos and Arvor-L models were included in this table because they are presented in the Chapter 3. Since they are older models, a majority are dead and their observed lifetime at sea are pretty reliable (especially Arvor-L floats). Were considered, for these models, floats deployed after 2010 and onwards.

	S2A (277 floats)	250 cycles	133 cycles	37	126 cycles	x		87%	41%
		10 days @4000m profiling depth							
DEEP	ARVOR-D (86 floats)	120 cycles (with additional DO measurements performed)	49 cycles	26	53 cycles	35%	100 cycles / 109	70%	28%
	APEX-D (46 floats)	?	88 cycles	18	103 cycles	x		61%	?
DEEP	NINJA-D (13 floats)	?	22 cycles	12	21 cycles	x		8%	?
	SOLO-D (70 floats)	250 cycles (**@6000m profile depth**)	120 cycles	14	174 cycles	x		80%	29%
		10 @ 2000m profiling depth – 6 variables							
BGC	PROVOR_III (60 floats)	250 cycles (minimum)	178 cycles	22	232 cycles	32%	360 / 370	63%	57%
	PROVOR_IV (38 floats)	250 cycles (minimum)	122 cycles	25	123 cycles	12%	130 / 179	34%	15%

ANNEX 2 - Survival rates comparison between the European and International array