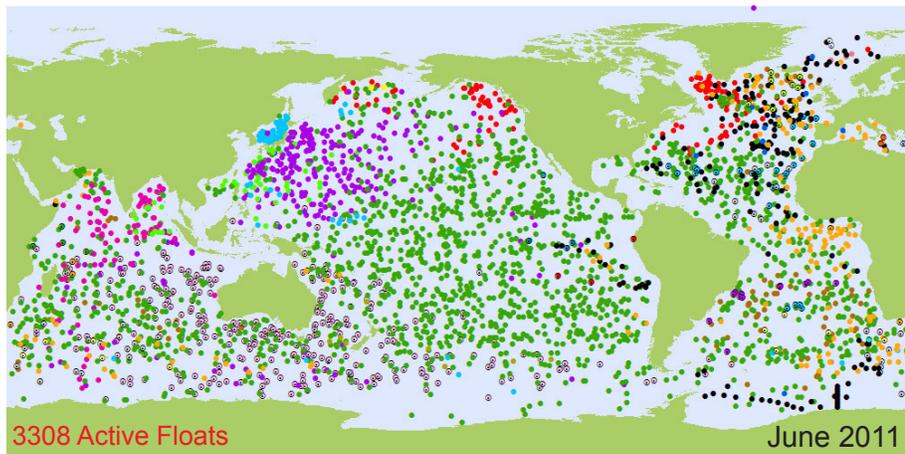




## Newsletter of the international Argo project

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### Notes from the Editor

Soon after the last newsletter in September 2009, OceanObs'09 occurred which gave Argo the opportunity to present its progress in the past ten years and to think towards the future. As a measure of how far Argo has come, the majority of the White Papers referred to Argo and the work it has done to become a truly international, global program. The meeting also generated feedback from users as to how Argo could expand the core mission by introducing new sensors and different mission parameters. In the almost two years following the meeting, Argo is continuing to explore ways to incorporate the expansion recommendations while maintaining the integrity of the current core Argo array.

This past spring, Argentina hosted the twelfth Argo Steering Team meeting. It was a good opportunity for oceanographers from South America to attend the meeting to learn more about Argo and to present their work using Argo data. There is a summary of the AST-12 meeting in the Newsletter, but the focus of the meeting included reviewing Argo's status and its future evolution. As the push to expand Argo increases, Argo continues to focus on securing sustained funding and ensuring the highest possible data quality.

Michel Ollitruault and Jean Philippe Rannou have done a tremendous amount of work on the Argo trajectory files to create a velocity data set named ANDRO. They spent time studying the three main float types to understand their mission details and even decoded raw ARGOS messages to improve the accuracy of the information in the trajectory data set. They plan on releasing the first version of ANDRO covering the time period of July 1999-December 2009 later this year. Please read the article for the complete details.

There are two articles on new float technology. The Deep NINJA float, developed by Tsurumi Seiki Co. Ltd. (TSK) and JAMSTEC, is described and aims to profile to a depth of 3000 dbar or more. An improved

engine makes this possible. There is also an update on the ARVOR float and some initial results from both Iridium and ARGOS-3 equipped floats. More analysis of the systems is planned for the future.

The list of Argo-related papers published this year is in this Newsletter as well as known papers in press. Due to space, we will be removing the citation list from the next Newsletter, but it is always available online at <http://www.argo.ucsd.edu/bibliography.html>. 2010 showed a large increase in the number of papers published - over 200 as compared to around 100 for the past several years. This is probably due to a combination of things including OceanObs'09 papers and more publications in both journals and books. If you publish a paper using Argo data or know of one published, please send [argo@ucsd.edu](mailto:argo@ucsd.edu) an e-mail with the citation.

Data quality continues to be a high priority of the Argo Program. Please see the notice on pressure biases within the Argo data set in the Newsletter. There continues to be a backlog of float deployments, so coordination among deployers is crucial. There is a new dedicated ship that can deploy floats called the Lady Amber. See the article in the Newsletter for more details.

Education outreach is becoming a bigger part of Argo and there is a note in this Newsletter describing the work being done by J. Gould and V. Byfield for EuroArgo. They are developing a web site resource aimed at 14-16 year old students. Dr. J. Hermes reported on work done in South Africa to incorporate Argo floats into their education program aimed at 15 & 16 year olds. The Argo TC has also coordinated updates to the Argo Google Earth layer to include much more information about each float and to showcase float stories based on the float of the month feature on the AIC web site. It is also possible to see what the entire Argo array is measuring with overlays of temperature, salinity and dynamic height over time and depth.

Megan Scanderbeg

# ANDRO: An Argo-based deep displacement atlas

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## Introduction

During the first decade of the 21<sup>st</sup> century, more than 6000 Argo floats have been launched in the World Ocean, gathering temperature and salinity data from the top 2000 m, at a 10-day or so sampling period. Meanwhile their deep displacements can be used to map the ocean circulation at their drifting depth (mostly around 1000 m). A comprehensive processing of the Argo data collected has been done to produce a world atlas (named ANDRO) of deep displacements fully checked and corrected for possible errors found in the public Argo data files (due to wrong decoding or instrument failure). So far, 75% (to be updated soon) of the world data have been processed to generate the present ANDRO displacements (which are based only on Argos or GPS surface locations). In a future version, improved deep displacement estimates will be based on float surfacing and diving estimated positions.

Float displacements at depth (roughly 8 days and a half over a 10 day total cycle time) provide estimates of absolute velocity (averaged over the displacement times) all over the world with an approximate 10-day sampling period. Although such a velocity field is mainly restricted to one depth (1000 m), if the estimates are accurate enough, it may solve the long-standing problem of the reference level (Wunsch, 2008 e.g.) for the first time. As far as the mean circulation is concerned the accuracy of the velocity estimates is quite sufficient (Ollitrault et al., 2006, e.g.) but may be questionable for studies focusing on monthly variations and in specific areas (as the equatorial band). It may seem strange to question the accuracy of Argo floats since ALACEs had already proven excellent (Davis, 2005 e.g.). But Argo floats go deeper (2000 m) and spend generally less time at their park pressures.

Yoshinari, Maximenko & Hacker (2006) first produced an atlas of velocity estimates (YoMaHa'05) by using the then available Argo data. YoMaHa'07 (Lebedev et al., 2007) is a regularly updated version (available at <http://apdr.csoest.hawaii.edu/projects/Argo/data/trjctry/>). This atlas uses Argo data from the public NetCDF files found on the Global Data Assembly Center (GDAC) web sites (<http://www.coriolis.eu.org/> or <http://www.usgodae.org/argo/>). Generally float displacements from YoMaHa'07 look quite realistic. But a few percent show high speed or have drifting depth obviously wrong (i.e., some are found drifting over the continental shelf while their drifting depth is given as 1000 m).

This convinced us to look more closely into the Argo data (and if possible to start anew from the very first Argos or Iridium raw data received at the different Data Assembly Centers (DAC)) for checking and (if necessary) correcting the various parameters measured by the floats and used to estimate the float displacements.

We present here what we have done so far with the data sets from AOML (USA), Coriolis (France), JMA (Japan), CSIRO (Australia), MEDS (Canada) and INCOIS (India) DACs (90% of the world data).

First the various floats used are presented: functioning, parking data measurement and transmission. Then the processing done on DAC NetCDF files and (available) Argos raw ASCII files is explained. In the third part, we present our deep displacement (velocity) atlas named ANDRO (for Argo New Displacements Rannou and Ollitrault, or because it is the name of a traditional dance of Brittany meaning a round or a swirl), resulting from our processing of Argo data. A last section explains what could be done to improve the deep displacement estimates.

## The various Argo floats

There are three main types of Argo floats: APEX, SOLO and PROVOR contributing 61%, 26% and 11% respectively to the total number of Argo floats used since 1999. A few other float designs have been developed (for example NEMO in Germany, PALACE in USA or NINJA in Japan) but contribute only 2%.

## APEX float

The APEX float is designed and manufactured by Teledyne Webb Research (USA). It uses an aluminum pressure case (16.5 cm diameter and 130 cm long) and a hydraulic mechanism to stabilize it at a prescribed depth. Each instrument is tailored and its mission programmed by the manufacturer, depending on the final user desires.

Four parameters are essential for the APEX mission: DOWN TIME which comprises the descent from the surface, the float drift at its park pressure and the (possible) descent to its deepest profile pressure, UP TIME which comprises the ascent from the deepest profile pressure and the surface drift with the ARGOS (or Iridium) transmission, PARK PRESSURE and DEEPEST (profile) PRESSURE. Thus APEX cycles are DOWN TIME + UP TIME long.

Prior to the first dive, APEX stays for 6 hours at the surface and continually transmits a test message, which contains the mission parameters. Then the float begins its mission proper, cycling until battery exhaustion. At the end of each cycle, a number of data messages (approximately proportional to the profile size) are sent repeatedly for several hours (usually 12h).

During the drifting phase, APEX regularly measures P, T & S triplets but only the last one (sampled at parking phase end) is transmitted. Newer APEX versions, however, also transmit statistics for P, T and S regularly sampled during the parking phase.

Because APEX floats have evolved since the beginning of Argo, there are many firmware versions. Presently we have developed 73 APEX decoders (all with Argos transmission).

## SOLO floats

The SOLO floats come in two models: the WHOI SOLO developed at the Woods Hole Oceanographic Institution on the East coast of the USA and the SIO SOLO developed at the Scripps Institution of Oceanography in California (both models contributing equally to the Argo fleet). These floats share the same pressure case with the APEX. However each float mission must be programmed by the user.

For the WHOI SOLO, each cycle is exactly N days long (10 days generally) and the time reference is at the beginning of the parking phase which is always at 0h (or midnight), when the float is supposed to have reached its park pressure.

The drift phase is usually 8 days and 5 hours long, then the float descends to its DEEPEST (profile) PRESSURE, usually reached within 4 hours. Thus, with these figures, the start of ascent is 8 d 9 h after the descent end, whether or not the deepest profile pressure was reached. The time to reach the surface is similar to that for APEX floats and also with APEX floats is not known a priori. The time for Argos transmission is typically 12 h.

During the drift phase, the float acquires 6 P, T and C (or S) triplets, if equipped with FSI (or SBE) sensors. The first and last triplets are taken at the beginning and end of the parking phase (thus 8 days and 5 h apart in our example). The four other triplets are measured 1day 1h, 3days 1h, 5days 1h and 7days 1h after the reference time. These are averages over the previous intervals.

There are three types of Argos messages: one for profile data, one for drift data and one for engineering data. The engineering message contains P, T and C (or S) at beginning and end of the drift phase, given in full range.

In the drift message, the four other P, T and C (or S) triplets are given as remainders modulo 409.6 dbar, 4.096° C and 1.024 PSU (or mS cm<sup>-1</sup>) respectively. With each of these four triplets, a very useful parameter is also given modulo 4096: the variation of volume of the float DV counted as number of turns of the piston driver. Actually,  $\Delta Park Pres = 0.75 * DV$  to a high accuracy, and this enables to solve the modulo uncertainties on the pressures measured during the drift phase.

The SIO SOLO functioning is rather different from the WHOI SOLO. All times except the rise time (for profiling) are fixed. For example with a mission at 1000 dbar (parking depth), the fall time is generally 500 min, followed always by two repositioning phases 5 h each (to get closer to the prescribed depth). The park time proper lasts 20 times a sampling interval (generally 20 times 557 min). Descent to deepest profile pressure is always 5h long, after which the float ascends as fast as it can by moving out its piston completely (a 1000 m rise takes roughly 2 h but this is slightly variable). Then the float transmits to Argos for a fixed duration (e.g. 18 h). While drifting at its parking depth, 20 measurements of P, T and S are acquired but only the averages for the first and second halves are transmitted.

There are two different message types: Data message for P, T and S measurements taken either during the parking or the profiling phases, and Engineering message for various parameters of the float functioning.

Presently we have developed 2 WHOI SOLO and 3 SIO SOLO decoders (all with Argos transmission).

#### **PROVOR float**

This float is designed and manufactured by NKE (previously TEKELEC then MARTEC) in partnership with IFREMER. It is slightly taller (1.60 m) than its American counterparts. Each instrument mission must be programmed by the user.

Each cycle (except the first one) is N days long and the reference time is at the beginning of the ascending profile (the day and hour of the reference time is programmable). PROVOR is controlled hydraulically to follow its park pressure within 30 dbar and does P, T and S measurements every H hours (generally every 12 h) while drifting. All these measurements are transmitted and many are dated by the float clock. PROVOR ascent velocity is of the order of 10 cm s<sup>-1</sup>.

PROVOR messages are of two types: technical and data messages. Technical messages contain information about the float functioning. Data messages come in three types: one for descending profile (if required), another one for the parking phase and a last one for ascending profile data. In each data message, there are between 4 and 16 P, T and S triplets with the first triplet dated.

Presently we have developed 19 different PROVOR versions using Argos transmission and 4 versions using Iridium transmission.

#### **Data processing**

From the NetCDF public Argo files, we first generate a data set (henceforth called DEP) comprising all the useful information given by the various floats. Then the data are checked, corrected and improved with information gathered outside or through a decoding of the original Argos or Iridium raw data files. Some complementary estimated data are also added. The final data set is then used to generate our ANDRO deep displacements atlas.

#### **DEP data set creation**

ASCII DEP files (there is one file for each float) are created from the public NetCDF (meta.nc, traj.nc, prof.nc and tech.nc) files. Argos (or GPS) positions, dates and location classes come from the traj.nc files together with the (real time) P, T and S measurements during the parking phase. Real time P, T and S values sampled during profile come from prof.nc files. A few other measurements or data are recovered from the meta.nc and tech.nc files, to be used in the future (for an improved version of ANDRO, discussed at the end of the paper).

#### **Argos raw data pre-processing**

In order to check and improve the DEP data set, we asked the DACs to provide the original Argos raw data. All Argos data from each DAC are first concatenated to be sorted afterwards by Argos PTT number. Then WMO float numbers are attributed to the data (sometimes one Argos PTT may have been consecutively shared by two or more different WMO numbers). Finally, the data are split into different cycles (there is one Argos raw data file for one received float cycle).

#### **Additional Argos (or GPS) locations**

Examination of the Argos (or GPS) raw data files revealed that some Argos (or GPS) locations are not found in the traj.nc files. Missing positions were added in the DEP files (sometimes improving the accuracy of existing ones because of a better location class).

#### **Argos Data decoding**

At the beginning of our work (in 2007) we discovered several errors on physical parameters given in the NetCDF files possibly due to unreliable decoding (for example roll-over errors for P, T and S parking values). Thus, we decided to decode anew the Argos (or Iridium) raw data (the DACs provided roughly 95% of the whole Argo dataset). Newly decoded park and profile P, T and S values are then added to the DEP files (they replace existing ones).

All floats (except SIO SOLO) have an error detection code imbedded in the Argos messages (called CRC for Cyclic Redundancy Check) that we have used to reject possibly corrupted messages. Furthermore among all the received copies of one transmitted message, the most redundant one is preserved.

#### **Meta data check**

At this stage, we are able to check the following parameters given in the meta.nc files:

- REPETITION\_RATE which gives the number of times the float does the same cycle mission (defined by fixed CYCLE\_TIME, PARKING\_PRESSURE and DEEPEST\_PRESSURE parameters),
- CYCLE\_TIME (theoretical cycle duration),
- PARKING\_PRESSURE (theoretical subsurface drifting pressure),
- DEEPEST\_PRESSURE (theoretical starting pressure of ascending profile).

These parameters (corrected if necessary) are stored in a separate file to be used in the following steps.

#### **Representative park pressure**

For each cycle, we determine a realistic estimate of the float parking depth, which is very important if we want to use Argo float deep displacements to track water motions.

This Representative Park Pressure (RPP) is computed as follows:

- If the float provides regularly sampled park pressure values, RPP is the average value,
- If the float only provides the mean of the (regularly sampled) park pressures, it is RPP,
- If the float provides only one park pressure (generally sampled at the end of the drifting phase), it is RPP,
- If the float provides the minimum and maximum pressures sampled during the drifting phase, RPP is the middle value,
- If no pressure measurement is available during the drifting phase, RPP is given by the theoretical PARKING\_PRESSURE value (in this case we need to check if the local bathymetry is not shallower and if the induced deep velocity seems realistic).

Then a systematic visual check on the RPP time-series is done to detect possible errors due to float pressure transducer ill function (mostly on APEX) or transmission error. Existing RPP values are then replaced by: a default value if the RPP is not correctable, 0 dbar if the float is obviously at the surface, the theoretical PARKING\_PRESSURE if the float seems to be working nominally.

#### **Cycle number**

To be reliable for scientific use, a deep displacement must be defined between two consecutive cycles. Thus it is very important to be confident in the cycle number. The check is easy with the APEX floats because they transmit the cycle number in one Argos message. For most of the other floats, we need to cross check the Argos (or GPS) location dates with the CYCLE\_TIME parameter.

#### **Unusable cycles**

If a float hits the bottom while drifting, it is considered grounded, and this cycle will be excluded from our ANDRO atlas. Grounded cycles are detected by comparing RPP with a precise local bathymetry (SRTM30+

worldwide bathymetric atlas).

Some floats are recovered at sea or after beaching, while still functioning. The corresponding cycles are deleted from the DEP files.

**ANDRO generation**

From the final DEP files, one then generates the ANDRO atlas, which basically contains the deep displacement estimates defined as the distance between the last Argos (or GPS) fix and the first Argos (or GPS) fix of two consecutive cycles. All GPS locations, but only Argos locations with classes 1, 2 or 3 (i.e. with 1km, 350m or 150m accuracy) are used. Furthermore only those Argos positions that pass the Nakamura et al. (2008) test are preserved.

**ANDRO actual contents**

ANDRO atlas is available as an ASCII file (containing 28 columns) whose format is identical to YoMaHa'07 (except we use WMO number instead of their float ID). Thus, in ANDRO, one finds float depths, deep and surface displacements, times, deep and surface associated velocities with their estimated errors.

Presently, ANDRO contains data from AOML and JMA until December 31<sup>st</sup> 2008, from Coriolis, CSIRO, MEDS and INCOIS until December 31<sup>st</sup> 2009 (later versions of ANDRO will cover the following years). There are a total of 5 258 floats contributing 465 896 displacements (over 481 907 cycles done). Table one and figure one give the displacement depth repartition.

**Towards better deep displacement estimates**

Actual deep displacement estimation relies only on surface locations. However, contrary to GPS locations, Argos positions are not (generally) available when the floats surface (or dive), but slightly later

Parking pressure (dbar)	Number of displacements ( 5,258 floats)	
0 < P ≤ 250	14,566	3.1%
250 < P ≤ 750	22,762	4.9%
750 < P ≤ 1250	332,650	71.4%
1250 < P ≤ 1750	50,095	10.7%
1750 < P ≤ 2250	39,426	8.5%
2250 < P ≤ 2750	82	0.0%
Undefined	6,315	1.4%
Total	465,896	

(or sooner) implying possibly a few km error on the deep displacement estimated (on average there is a delay of one hour or two). To estimate the true surfacing or diving

positions, one needs to determine first the corresponding times, to then extrapolate the surface float trajectory (sampled by the Argos locations) at these times.

For most of the floats, the surfacing time can be precisely estimated (within a few minutes), contrary to the diving time, for which one can use the envelope method proposed by Park et al. (2005). We have presently estimated these times for all floats except the SOLOs.

The extrapolation can be done, for example, by fitting a uniform velocity and a circular inertial motion to the Argos fixes (Park et al., 2004). We have tested this method on 750 floats, but with partial success (consequently, those estimates have not been saved in the DEP files yet).

Figure 4 gives an example of such an extrapolation (with a good fit), showing a large distance (13 km) between surfacing and the first Argos fix. Fortunately this is not representative of the general case: our study with 750 floats gives an average delay (after surfacing or before diving) of 80 ± 60 min implying an average 1.5 ± 1.5 km error.

A second planned improvement will consist in estimating the current shear between the surface and the parking depth, in order to be able, using a modeled vertical float velocity, to integrate the horizontal motion of the float during descent and ascent.

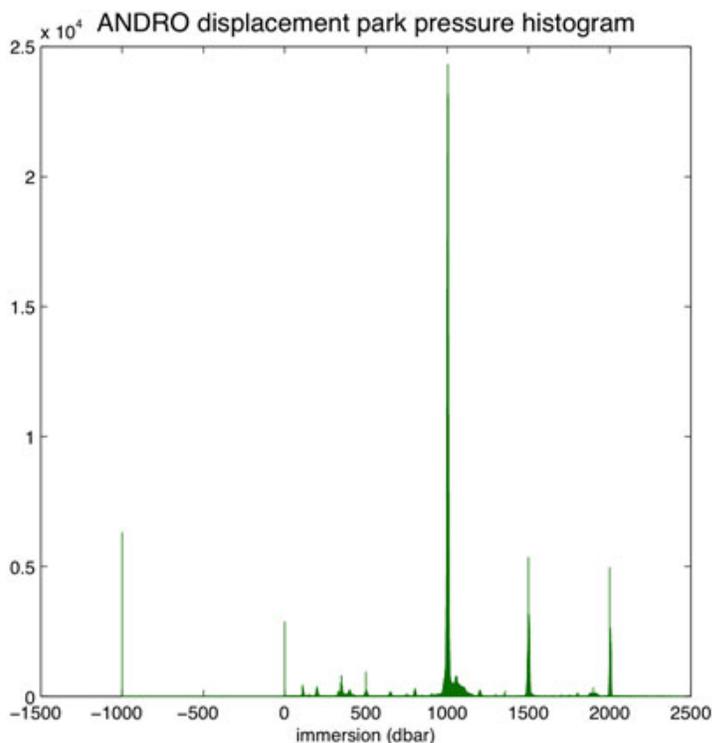


Figure 1: ANDRO displacement depth repartition. Ordinate gives the number of displacements within 1dbar layers. Unknown depths are defaulted to -999.9.

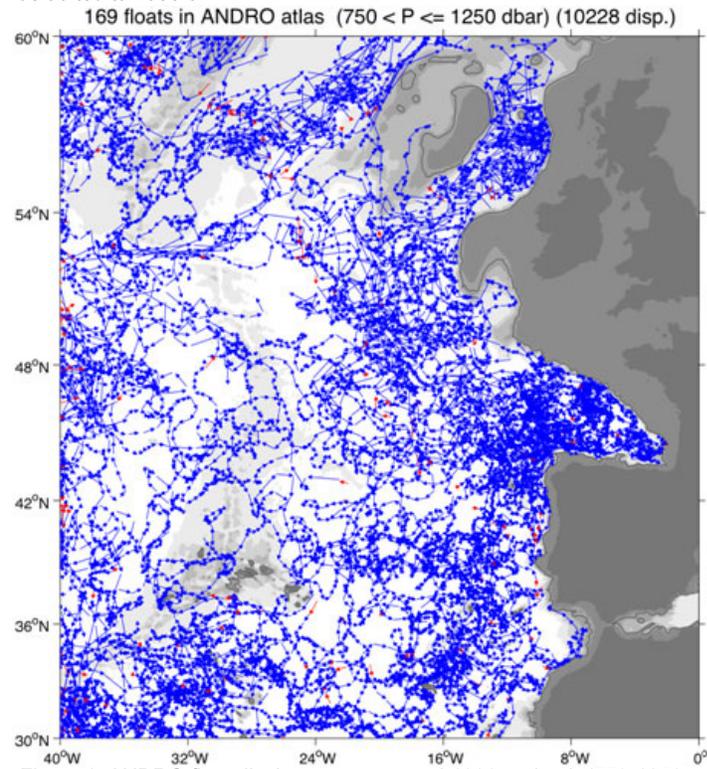


Figure 2: ANDRO float displacements around 1000 m depth (750-1250 dbar layer). Red arrow corresponds to first displacement of a given float.

**Conclusion**

Almost all ANDRO atlas displacement depths are *insitu* measured values. YoMaHa'07 displacement depths are only copied from the meta.nc files, implying erroneous drifting depths for almost 7% of the displacements (even with perfectly filled meta files, 4% would remain, due to instrument malfunction).

Thanks to the Argos and Iridium raw data provided by the DACs, we have been able to get rid of decoding errors and to concentrate on the float functioning. Furthermore we have slightly enlarged the Argos data set with cycles not publicly available (for reasons unknown to us).

Meanwhile, the DACs progressively update their NetCDF data files, as a result of our work. Since YoMaHa'07 atlas is regenerated periodically, the differences between ANDRO and YoMaHa'07 will tend progressively towards 4% due to instrument malfunction.

Before the end of this year, we shall process the AOML and JMA data for the year 2009, and the rest of the world Argos data (presently lacking in ANDRO) from BODC, KORDI, KMA and CSIO DACs. After completion, the ANDRO atlas (covering the period July 1999 to December 2009) will be freely available on the Coriolis web site by the end of 2011.

### Acknowledgements

The authors wish to thank Claudia Schmid (AOML), Taiyo Kobayashi (JAMSTEC), Ann Thresher (CSIRO), Udaya Bhaskar (INCOIS), Mathieu Ouellet (MEDS) and Thierry Carval (Coriolis) for sharing their data and cooperating strongly with us. We owe much to John Gilson who introduced us to the SIO SOLO subtleties. Brian King (NOCS) helped to convince IFREMER to support this study, following an initial suggestion from Pierre-Yves Le Traon (IFREMER). Last but not least, we would not conclude without thinking of our late colleague Gérard Loaëc, who was the main designer of the PROVOR float: this study is a tribute to his memory.

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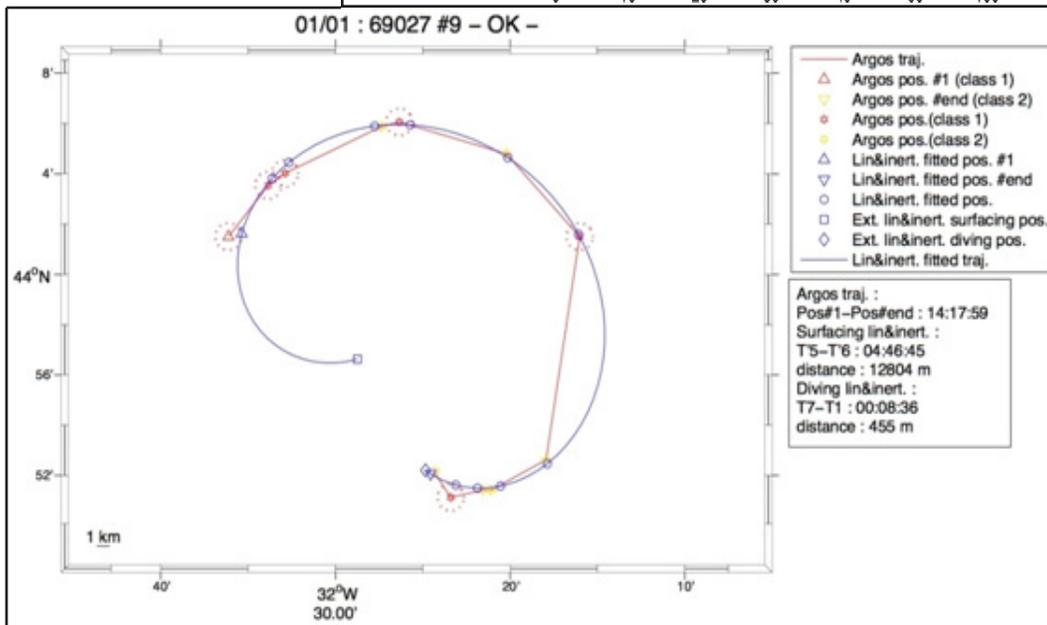
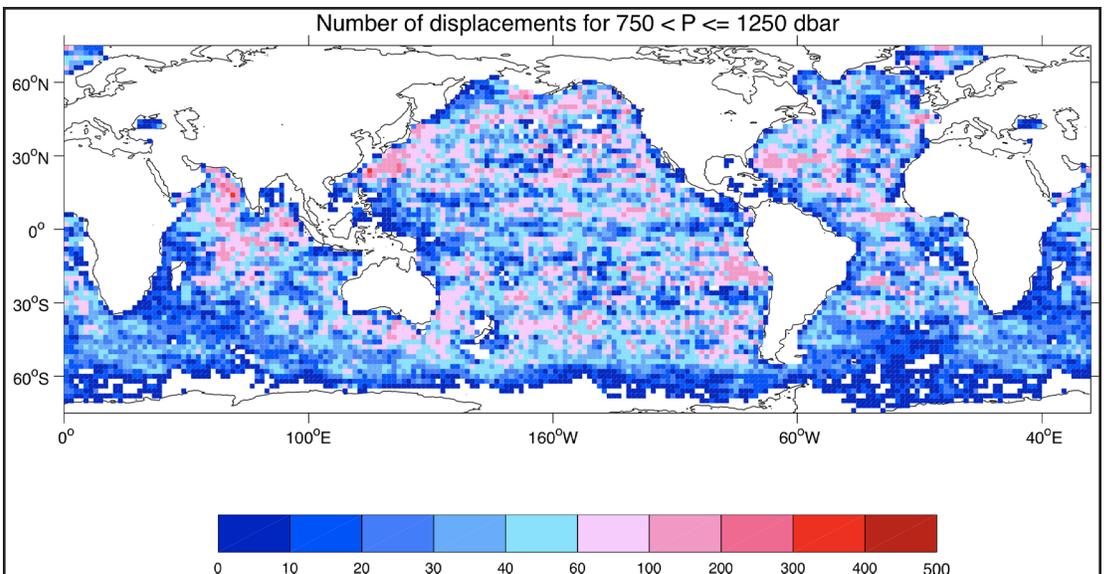


Figure 3: ANDRO world displacement atlas for the 750-1250 dbar layer.

Figure 4: Least square fit of a uniform velocity plus a circular inertial motion on Argos fixes, with extrapolated surfacing and diving positions. Dotted circles are Argos location 1 sigma uncertainty.

## Euro-Argo user workshop- the start of a new phase

John Gould, National Oceanography Centre, Southampton [wjg@noc.soton.ac.uk]

For the past 2½ years, European countries participating in Argo have been developing the means to make a truly European (in addition to national) contribution to the project. This preparatory phase of Euro-Argo is now close to completion and has resulted in new countries becoming active participants and in the development of a diverse user community. In the coming months, a European Research Infrastructure Consortium (ERIC) will come in to being to support Argo and ultimately to ensure that Europe contributes 25% of the global Argo

as Dean Roemmich from the USA who gave a keynote address noting both the remarkable progress Argo has made in exceeding the goals defined at OceanObs'99 but also noting the new challenges of data management and uncontrolled data access.

As usual the meeting was a mix of oral presentations (30), posters (20) and plenary discussions. (The full report of the meeting, together with oral presentations and posters, will be available on the Euro-Argo web site at <http://www.euro-argo.eu>).

ocean temperature profiles using unpumped samples. There was considerable interest from operational groups represented at the meeting (ECMWF, Mercator Océan) in expanding the availability of these data as a means of reconciling assimilated data from SST products and from ocean profiles. However caution was expressed about the data management issues caused by having two, essentially different, temperature data streams for each profile. It was felt that more work was needed to assess the value of these data.



array (compared to the present 15%).

The progress towards forming ERIC has come about in part through a series of annual Euro-Argo user workshops that were an integral component of the preparatory phase. The first was held in Southampton in 2008, the next in Trieste, Italy in 2009 and the most recent in Paris, June 17-18, 2010.

The Paris workshop was held in the historic Institut Océanographique, part of the Foundation established by His Serene Highness Prince Albert 1<sup>er</sup> of Monaco in 1910. (The more famous part of the Foundation is the Oceanographic Museum in Monaco). Almost 70 participants met in the grand lecture theatre of the Institut surrounded by murals on Prince Albert doing oceanography aboard his yacht the Princess Alice. There were 70 attendees from 13 European countries (Belgium, Bulgaria, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Spain, UK) as well

Though scientists who had participated in the two earlier workshops were unable to attend - Do we hold too many meetings? - The workshop showed the breadth of science being undertaken in Europe ranging from global-scale analyses of climate indices (Birgit Klein) and of the 3-D circulation (Sandrine Mulet) to the application of Argo data to fisheries biology in the Norwegian Sea (Kjell-Arne Mork) and ocean biogeochemistry (Hervé Claustre). The papers stimulated considerable discussion (more so than at previous workshops).

Discussion was focused on the contribution that Argo (and Euro-Argo in particular) might make to a small number of science themes: Ocean heat storage and sea level rise: The strength and stability of the MOC: Ocean biogeochemistry: and Improving the calculation of air-sea fluxes. This last topic also drew attention to moves in Europe and elsewhere to measure high-resolution upper

Attention finally turned to the form that Euro-Argo user workshops might take in the coming ERIC phase. Though previous Euro-Argo user workshops had encompassed all aspects of science, it was felt that in the coming years it might be more fruitful to focus the meeting on Argo's contribution to particular science issues such as the ones used in Paris. There were a significant number of very new users of Argo data at the Paris workshop and they requested that there should be a readily accessible (probably primarily web-based) introductory guide to Argo and its data. This could include recordings of lectures on Argo and might also be supplemented by taught courses or even a summer school.

Euro Argo is now entering an exciting new phase and we hope that within the coming months, despite the constraints being placed on national budgets, the enhanced European contribution to Argo will become a reality.

## Deep NINJA: a new float for deep ocean observation developed in Japan

Taiyo Kobayashi [taiyok@jamstec.go.jp] and Toshio Suga [suga@pol.gp.tohoku.ac.jp]

We are very happy to introduce a new profiling float for the deep ocean, Deep NINJA. It has been developed since 2007 by Tsurumi Seiki Co. Ltd. (TSK) and JAMSTEC and recently a prototype was built (Figure 1). Specifications of the system are the following:

- Height: 198 cm (with antenna)
- Weight: 76 kg in air (including floating collar)
- Diameter: 18 cm for hull and 37 cm for floating collar
- Maximum observing depth: 3000 dbar
- Sensor: CTD sensor for deep floats developed by Sea-Bird Electronics. Additional sensors can be added on board.
- Communication: Iridium (float locations are fixed with GPS system)
- Battery: Lithium
- Lifetime (est.): 120 cycles (2000-dbar dives except for a 3000-dbar dive every four cycles)

Now we are considering the possibility of enhancing the maximum depth of the prototype to 4000 dbar.

One of the most important features is its buoyancy engine (Figure 2), which was newly developed for Deep NINJA. It has a new mechanism, which is a hybrid of the two existing systems, the single-stroke piston and the hydraulic pump. The engine was tested at up to 3500 dbar without incident in the laboratory and it can generate significant float buoyancy when adequate oil is provided in the interior reservoir. These two features are essential to buoyancy engines for deep floats. Another advantage of the engine is reliable control of buoyancy even at that depth. The shorter engine piston results in a smaller float, which translates into a longer lifespan of the float, too.

The new engine brings many benefits to the Deep NINJA, most importantly that the float is able to make observations below 2000 dbar. The Deep NINJA is expected to have a large payload capacity, which is a result of the new engine design.

Deep NINJA operating software is now being developed and will be finished by the end of August. In the fall of 2010, the first field test is planned to be carried out in coastal waters. After multiple field and laboratory tests, the first dive to a depth of 3000 dbar was planned for May 2011. We expect to present the test results in the next year.

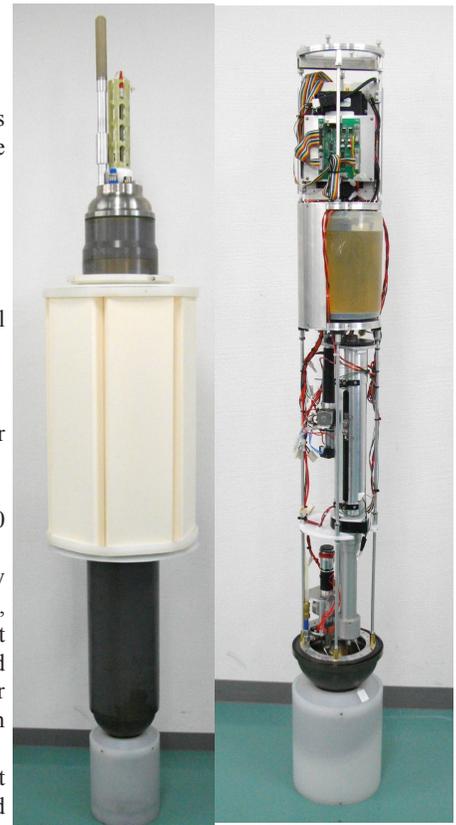


Figure 1: A prototype of Deep NINJA

Figure 2: Machinery of Deep NINJA

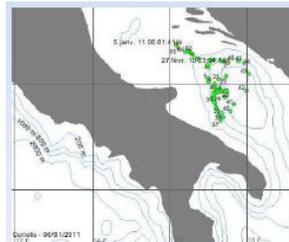
## ARVOR communication improvements for marginal seas applications

Serge Le Reste [Serge.Le.Reste@ifremer.fr] and Xavier Andre [xavier.andre@ifremer.fr]

New requirements have appeared in the last few years for profiling floats and the ARVOR float is being made to meet these new requests. The two main requirements are less surface time and the ability to modify mission parameters after deployment to monitor specific events. For deployment in marginal seas, less surface time is needed in order:

- to lower the risk of thefts, trawling or impact in these highly trafficked seas
  - to delay the time of beaching on the shores
  - to have better estimates of subsurface currents
- For coastal applications, the reduction of surface time:
- facilitates the realization of successive profiles at the same location to delay beaching
  - delays the development of bio-fouling

As a solution to reduce surface time and allow for mission modification, ARVOR floats have been fit with both Iridium and ARGOS-3 communications. An Arvor float has been fitted with an Iridium modem coupled with a GPS receiver and a high pressure antenna, for Argo marginal seas requirements. Using Iridium allows extra information about the behavior of the float to be sent. Additionally, a last CTD raw data is acquired before stopping the CTD pump at the end of the rising profile (useful for knowledge of surface properties). There is improved vertical resolution (2 dbars) and power balance, as well as remote control avail-



Arvor-I trajectory in Adriatic sea

**\*1st prototype**  
Deployed in the south of Cyprus (Dec. 2009).  
1 cycle / day from 700 m depth.  
255 cycles has been done.

**\* 2nd prototype:**  
Launched in Adriatic sea (Feb. 2010), 92 cycles of 5 days done (still cycling).  
Several remote commands have been sent to the float in order to modify the cycling period and the profile depth.  
3m only are needed to transmit a high resolution sampled data profile (every 2 dbars). Time spend at surface is around 40 mn.

Now, Arvor-I is currently used in Argo program

able during operation (modification of cycling period, parking depth, profile depth...). The capability to manage seabed stationing is proven at sea.

Assessment, integration and testing at sea of the ARGOS-3 communications has been done.

The system works with the interactive mode capability (low data rate) of the MetopA satellite. It uses its prediction pass tables to make a rendez-vous at the surface. Argos2 standard communication is maintained in case of interactive mode failure.

Two floats have been deployed in the Mediterranean Sea in February 2011. The floats have done more than 30 cycles and the synchronization of the float with the Argos3 satellite pass is accurate. A few data sets have been sent in one Argos3 satellite pass, showing the interest of the system, however, the time spent at the surface is variable and has to be improved. More analysis is planned as well as improvements and high data rate implementation for 2012.



## Report on the Twelfth Argo Steering Team Meeting

Megan Scanderbeg [mscanderbeg@ucsd.edu]

The 12th meeting of the international Argo Steering Team was held in Buenos Aires, Argentina on March 15-17, 2011. AST-12 focused on how Argo will be sustained and enhanced in the coming years. As Argo begins considering how to implement changes suggested at OceanObs'09, there remains a push for sustained funding and for ensuring the highest possible data quality.

### Implementation issues

The Argo Technical Coordinator reported that Argo has nearly reached its core array goal, but that maintaining this array is going to prove quite challenging. Some countries have reached their funding limit, so new countries need to be brought in to help sustain and grow Argo. On the other hand, most float types have reached original lifetime goals and the percentage of delayed mode profiles has risen to 86% of eligible profiles. One change over the past year that is likely to occur even more is the expansion of floats equipped with Iridium sensors. In 2010, 18% of floats being deployed had Iridium communications.

Euro-Argo will transition in early 2012 into a long term European research infrastructure with a legal status (Euro-Argo ERIC). ERIC will provide strong visibility for Argo in Europe and will allow European countries to consolidate and improve their contribution to Argo. Overall, Euro-Argo members hope to contribute 250 floats per year. In addition to the Argo core array requirements, EuroArgo has requirements for marginal seas, high latitudes and additional sensors. There is also a recommendation for a deep float pilot program and design study.

AST members updated the commitments table and the expected number of deployments for 2011 is again large (~1000). About 800 floats were deployed last year, less than the roughly 1200 expected. This was mainly due to difficulty finding and arranging deployment opportunities or a lack of available CTDs for floats. SeaBird has said there should no longer be a shortage of CTDs. Even with so many floats in inventory, it will likely take a couple of years to deploy all the backlogged floats.

To help find and coordinate deployment opportunities, the ATC is exploring funding a position to track down cruises and make that information available to Argo, DBCP, etc. The *Lady Amber* is a new option, in addition to the *Kaharoa*, for a dedicated ship to deploy Argo floats. It has already taken its first voyage to deploy floats and is ready to accept more in September. See the article on page 11 for more details.

Hosoda presented on two forums that were held in Japan in 2010 to build consensus on the future direction of Japan Argo. Two conclusions were agreed upon at the forums. The first being that Japan Argo should continue to contribute to Argo by sustaining the current level of float deployment and data management activities. The second being that Japan Argo should contribute to a new integrated ocean observing systems, based upon the Argo core array, which will increase climate monitoring and research capability and provide information on the marine environment to better meet society's needs. As a start on the second goal, twenty-five dissolved oxygen floats will be deployed as Argo equivalent floats in the experimental area of 150 km x 150 km in collaboration with other observational platforms such as moorings, ships and satellites.

H. Claustre reported on the progress of the Bio-Argo working group. As a result of two meetings attended by scientists from complementary expertise, three main classes of bio-optical and biogeochemical floats have been proposed. The Bio-Argo float is proposed as a rather simple float with respect to the optical package [Chl<sub>a</sub> fluorescence, backscattering (proxy of POC)] that could become part of the Argo array, respecting the core Argo mission rules. Presently ~150 floats are to be deployed within the next 18 months. The Bio-Argo community is also involved in the various aspects of data management and delayed mode quality control.

### Data Management related issues

Overall, Argo's data management infrastructure is stable, but requires monitoring tools at the AIC, GDAC, and ARC levels and requires manpower at the DACs to correct anomalies as they are detected. The current ADMT efforts are focused on reducing delays, delayed mode quality control, improving data consistency and completeness and detection and correction of systematic errors/biases. The pressure offset

correction and TNPD identification was recognized as the highest priority for DM operators. Much work has been done on this, but it still needs to be finished. The DM file checker is still under validation at the US GDAC. Its completion is critical to reduce the submission of DM files with anomalies. The next priority for the ADMT will be trajectory data. It was agreed that a trajectory workshop for DACs and operators engaged in preparing traj.nc files should be organized alongside the next ADMT.

The Argo DACs are working hard on identifying, correcting and labeling Argo profiles that might be affected by pressure sensor bias. This involves correctly populating technical files with reported pressure offsets, correcting profiles that require it and identifying APEX floats with APF8 or earlier controllers and possibly negative drifting pressure sensors, known as Truncated Negative Drifting Pressure (TNPD) profiles. Great progress has been made by DACs on pressure drifts where known. However, Argo did not achieve its goal of having all corrections and TNPD labeling completed by December 2010. Even so, most large DACs are nearly complete and most egregious cases have been treated. TNPD identification and treatment is not as far along, but is progressing. This may require further focus by the DACs and smaller DACs might need assistance in finishing compliance and improving decoders.

B. King presented a status update on the work of J.-P. Rannou and M. Ollitruault who continue to re-decode Argos hex files provided by DACs and to correct errors. The goal is to complete all Argo data through December 2009 by the end of 2011. Additionally, work has been done to extract and save extra information not stored in existing traj.nc files. For more information, see the article on page 2. B. King and a small group are working on a proposal for a traj\_version2.nc file which will include extra timing information to easily enable users to pull out data useful to velocity calculations. This will be discussed at the trajectory DM workshop in conjunction with the next ADMT.

### Technical issues

An update was given on PROVOR and ARVOR float technology. Both floats are being equipped with new sensors and communications. See the article on page 7 for more details on the ARVOR. As for the PROVOR float, oxygen sensor technology is now considered mature and work is being done to implement a nitrate sensor and a "NOSS" density sensor. Finally, developments will be done on PROVOR and ARVOR floats within the French NAOS project to reduce costs and to improve float reliability and lifetime.

S. Riser presented on four developments including APEX air pump solenoid problems, some first tests of ARGOS-3, and SBE conductivity drift. The air pump is controlled by a solenoid, many of which, for reasons unknown, have failed in lab tests at UW in recent months. A failure would mean the air bladder would not inflate, resulting in the possible loss of the ability to communicate with a satellite. This is especially problematic for Iridium floats. The problem can be corrected by adding a small, inexpensive, printed circuit board near the solenoid. As of March 2011, Teledyne/Webb was notified of the problem and the suggested remedy, but they continue to build and ship floats with this potential problem.

UW has developed a prototype float that uses a Kenwood PMT to communicate with ARGOS-3 satellites. The first tests of the Kenwood PMT have shown that energy use is larger than with present ARGOS-2 PTTs. Finally, both Jamstec and PMEL have noted APEX floats with unacceptable conductivity drift after deployment (> 0.01 PSU equivalent). The cause of the problem has been found and new QC procedures have been installed at SBE. It is believed that this problem occurred in an isolated group of floats (CTDs built in late 2010) but all groups should check for this.

D. Roemmich presented an update on the SOLO-II which is now commercially available through MRV Systems (<http://www.mrvsys.com>). The SOLO-II is engineered to complete around 300 dives anywhere in the world ocean using Iridium. It weighs less and is shorter than the SOLO making it easier to deploy. Two SOLO-II prototypes have been deployed and completed many successful cycles. US production of the SOLO-II will be done by both SIO and MRV. 15 SOLO-II floats have been sent to

## EuroArgo's educational outreach web sites

John Gould [wjg@noc.soton.ac.uk]

One of the tasks for the EuroArgo project (<http://www.euro-argo.eu/>) was to develop a web site that provides a "window" on the project for non-specialists. This has been masterminded by John Gould and Val Byfield of National Oceanography Centre (NOC) and is now almost complete (<http://www.noc.soton.ac.uk/o4s/euroargo/> and Figure 1). As well as giving background information about Argo it uses Google Earth's platform to highlight a number of floats (mostly deployed by European countries) to explain some basic facts about the ocean, its role in climate and the structure of float profiles. The web site presently interfaces to existing educational outreach information on the NOC site and is pitched at a level that should be accessible to 14-16 year-olds.

There is scope to further "internationalize" the site by adding other float stories and linking to other labs' educational material. The site is also a focus of a project in which we are enlisting the assistance of Rotary Clubs (presently in the region around Southampton) to provide a link between their local schools and the NOC in a project called "Young Eyes on the Oceans" (Figure 2). This is a model that could, ultimately, be developed globally with Rotary Clubs near the labs involved in Argo.



Figure 1: EuroArgo Educational Outreach Web Portal

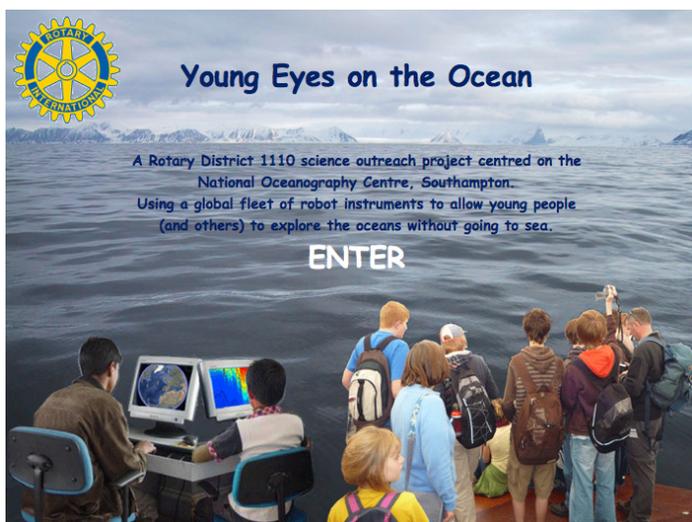


Figure 2: Web site linking Rotary in Southampton and Argo outreach

continued from page 8

Papeete for deployment along the equator with more than 150 floats to be built in 2011.

Howard Freeland and Denis Gilbert reported that the MetOcean Corporation of Dartmouth, Nova Scotia, is currently developing a new float they call the NOVA float. We have seen no data from this float yet and do not know when these will likely be available to launch.

Jon Turton outlined some results from preliminary analysis of data from eight Near Surface Temperature-capable (NST-capable) APEX floats deployed by UK. Although relatively few stratified profiles were observed, the results show the NST-capable APEX floats are able to observe near-surface temperature stratification that would otherwise remain undetected and so do provide useful additional information. More work is needed to further explore the NST-capable floats.

S. Wijffels reported on work done by E. Van Wijk and others on the prospects for extending Argo into the seasonal and fast ice zone. Mortality rates of newer ice floats are now equivalent to those deployed in less demanding conditions, but the short surface time associated with Iridium is also a likely factor. A quick comparison among ice-float deploying groups shows a survival rate of around 80%. Extending Argo into the seasonal ice zone would require an additional ~600 floats. It was suggested that Argo continue to pilot ice-capable floats in order to refine the technology, but to also explore alternative sampling platforms.

### Demonstrating Argo's value

Dr Juliet Hermes presented on the South African Environmental Observation Network education program, of which Argo floats form a key component. Please refer to the short article on page 10 to learn more. Dr. Hermes also gave details of South African activities of interest to the Argo community and highlighted that all South African marine institutes have potential to be more involved with Argo over the next five years. A new vessel is commissioned for 2012 and there will be more float deployment opportunities aboard ASCLME cruises.

M. Scanderbeg presented on the development of the Global Marine Argo Atlas which uses Ferret to create plots of gridded data. Currently, the PC version of the Atlas comes with the 4-D gridded Argo dataset made at Scripps Institution of Oceanography (Roemmich and Gilson, 2009), the Reynolds SST dataset, and the AVISO dataset. It is possible to create map plots, section plots, time series, line drawings and a few simple products. Both postscript and jpg outputs are available for plots that are created using the Atlas. Both NetCDF and ASCII outputs are available containing the data used to create the plots. Besides giving a quick view of the datasets, the Atlas is a great way to compare datasets quickly. A Mac and Linux version should be available soon.

S. Diggs and the Argo TC presented work done on the Argo layers for Google Earth. The application is ideal for network tracking, searching/ retrieving beached floats, planning float deployments, as well as demonstrating and promoting Argo to the general public. Please refer to the article on page 11 for more details. Besides information balloons on each individual float, a layer of float stories has been added and overlays of temperature, salinity and steric height (data from 100% Argo gridded product from Scripps Institution of Oceanography) are now possible. Once the final version is finished, it will be proposed to Google for inclusion into their Google Ocean layer.

<i>Timetable of Argo meetings</i>		
2011-2012		
October 18 2011	San Diego, CA	Joint Argo and Altimetry Workshop hosted by OSTST
November 14-18, 2011	Seoul, Korea	ADMT-12
March 2012	Paris, France	AST-13

## Preliminary Report from the Argo-Oxygen Users Workshop, 25-27 May 2011

Stephen Riser, University of Washington, USA [riser@ocean.washington.edu], Virginie Thierry, IFREMER, France [virginie.thierry@ifremer.fr], Denis Gilbert, Institut Maurice-Lamontagne, Mont-Joli, Canada [denis.gilbert@dfo-mpo.gc.ca]

The fundamental design specifications of the Argo array are to measure temperature and salinity in the upper 2000 m of the world ocean at roughly 3° spacing, within 60° of the Equator, at approximately 10 day intervals. Presently these criteria are all generally being met. Due to this success, in recent years there have been discussions about expanding the mission of Argo to include deeper sampling, operation in ice-covered

regions, and the addition of biogeochemical sensors to a subset of the floats in the array. In the latter case, some significant preliminary work has already occurred. A dissolved oxygen sensor was first added to a float in 2002, and at the present time there are over 200 Argo floats carrying oxygen sensors, as can be seen in Figure 1. While the case for measuring dissolved oxygen in Argo has been made in the white-paper report by Gruber et al. (2011), to date most floats with oxygen sensors have been deployed on an ad hoc basis; until now, there has been no overall framework to examine the quality of the data or a coordinated plan for the use of these observations.

To examine the future of oxygen sensors in Argo and to attempt to assess the usefulness of the data collected so far, a workshop sponsored by Argo was held at IFREMER in Brest, France, 25-27 May 2011. The topics outlined for discussion at this meeting included a review of the present oxygen sensors available for use on profiling floats, the methods and quality of calibration of these sensors, the errors inherent in these sensors, the comparison of oxygen data from floats with the climatological database, and some scientific conclusions resulting from the sensors that have been deployed on floats to date. Forty-four scientists from 11 countries attended the workshop.

The meeting began with a discussion of the types of oxygen sensors available for profiling floats. One sensor in wide use is the SeaBird Integrated Dissolved Oxygen sensor, or IDO (also known as the SeaBird 43). This is an electrochemical (Clark cell) sensor similar to the oxygen sensors used on shipboard CTD systems. It is generally well-calibrated at the factory, and the use of the SeaBird IDO on floats has yielded some interesting scientific results (Riser and Johnson, 2008). Often, however (in more than half the cases), the IDO sensor exhibits a strong drift over time, rendering it undesirable for float missions lasting several years.

Presently the most widely-used sensor is the Aanderaa Optode 3830, first discussed and successfully used by Körtzinger et al. (2004, 2005). Over 130 sensors of this type have been deployed on Argo floats; the sensor is popular due to its demonstrated long-term stability. Aanderaa has a new version of this sensor, the Optode 4330, that is just beginning to come into use. The Optodes are optical sensors and operate by measuring the influence of dissolved oxygen on the fluorescence of a light-sensitive foil in the sensor. The sensor electronics examine the phase of this photo-response (the B-phase) and, with a temperature measurement made at the sensor and an assumed calibration relation, deduce the oxygen concentration in the surrounding water. While the Optodes are very stable over times of several years, they are generally not well-calibrated at the factory, and their offset from climatology can be quite large.

The Optodes 3830 and 4330 are attractive because of their long-term stability, and as a result, a great deal of the discussion centered on ways to calibrate these sensors and improve their accuracy. Ideally, the sensors should be well-calibrated at the factory, but at the present time

this is not an option. Several groups stepped forward at the meeting and offered to calibrate Optode sensors for the community at a reasonable cost, and this appears to be a promising option for the future. It is likely that *insitu* laboratory calibrations of the Optode will be pursued at several venues in the coming months, with results from various laboratories compared, so that the Argo community can better assess the limits of the accuracies of these sensors.

It is too late, however, for laboratory calibration of the sensors that have already been deployed, so the discussion turned to adjusting the oxygen values measured by the Optode to local oxygen climatologies. The global oxygen database, such as can be found in the World Ocean Atlas (WOA), is much sparser than the analogous archives for temperature and salinity, making such comparisons difficult. Even with this limitation, however, it can readily be seen (see Figure 2) that the error in oxygen measured by the Optode varies over the water column, and that the offset can be considerable, as much as 12  $\mu\text{mol/kg}$  as an average between the surface and 2000 m.

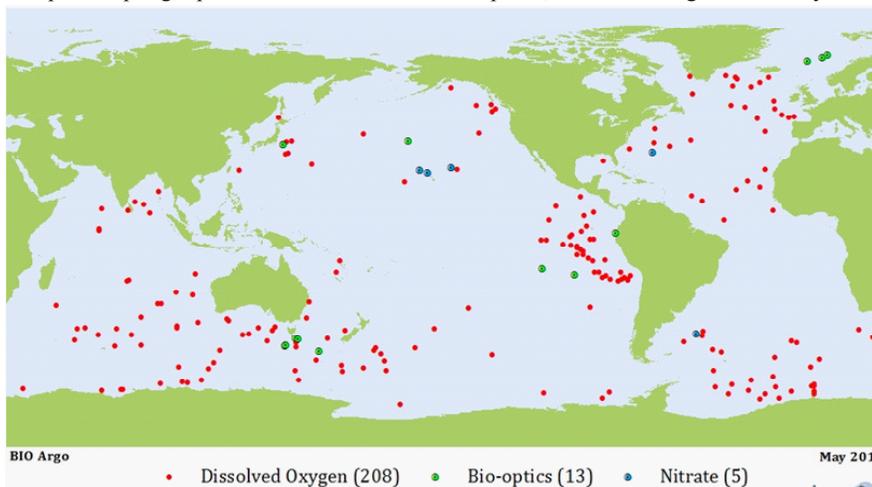


Figure 1. The distribution of biogeochemical sensors on Argo floats as of May 2011, provided by the Argo Information Centre.

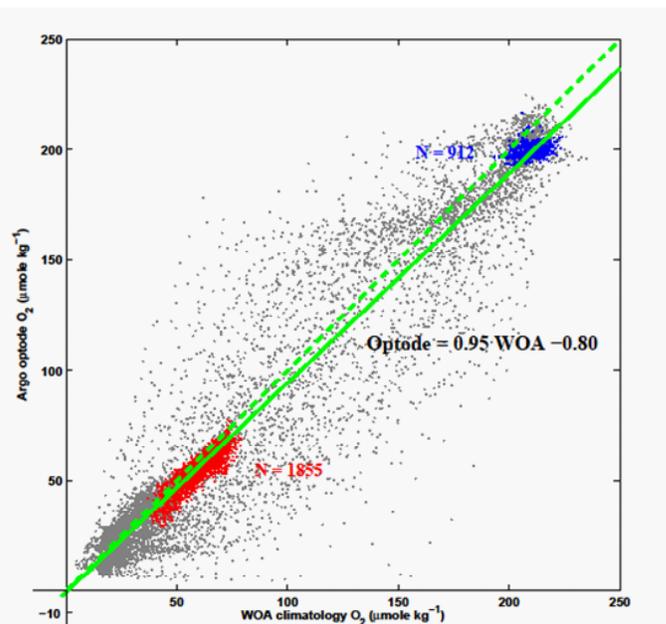


Figure 2. A plot of the dissolved oxygen measurements from University of Washington float 5089 (WMO 5901339) for the period 8/21/2006 to 5/17/2011, compared to the climatology from the World Ocean Atlas (WOA) 2009. The float data are from the North Pacific in the vicinity of 15°N, 160°W. Data from the upper 100 m of the water column (blue points) and lower 200 meters of the water column (1800-2000 m, red points) are used in this analysis. The dotted green line shows perfect correspondence; the solid green line shows the linear least-squares regression. Data between 100 m and 1800 m (gray points) are not used in this analysis due to the poor climatology in this region of the water column. The results shown here are typical of Optode results from throughout the world ocean. continued on page 13

## Argo Outreach activities in South Africa

Juliet Hermes [juliet@saeon.ac.za]

Argo floats form a key component of the South African Environmental Observation Network (SAEON) education program. Dr. Juliet Hermes (SAEON) collaborates with several people including Thomas Mtontsi (SAEON), Isabelle Ansoorge and Chris Reason, University of Cape Town and South African National Antarctic Program and Johan Stander, South African Weather Service. This educational program creates a platform where Marine Science Research can be integrated into School Sciences curriculum (with buy-in from the Department of Education). The program is comprised of three main thrusts:

- Educator/teacher support through workshops and forum meetings (train the trainer)
- School based monitoring programmes: Argo Floats and Adopt a Drifter Programme and weather and climate monitoring with weather stations.
- Additional learner/ student support in Science Camps comprised of short leg sea cruises

The program currently works with five previously disadvantaged schools, four of which are from coastal communities. The aim is to add a further coastal school by end of this year. The schools work on individual projects but monitoring groups get together at weekend camps to exchange ideas and problems. Since SAEON has six different focal nodes with similar education programs (one is coastal), the aim is to take the program to inland schools, some of whom have no concept of the oceans.

The education program provides a focal point for marine education activities and collaborates with all marine institutes to provide support and prevent duplication. There is also active involvement in marine awareness activities, reaching thousands of learners, as well as the general public. Several areas of the South African curriculum could integrate Argo floats and data:

- Focused groups at the school community – monitoring teams and the teacher/educator are responsible for downloading data
- For use in Mathematics, physical science, life sciences, Geography and Natural Science activities
- Grade 10 and 11 (ages 15 & 16)
- Excellent, fun tool for awareness activities



Students with Thomas Mtontsi on a Science camp cruise

As the program is always looking to improve and expand, any collaborations with other school programs using Argo data would be of great value. If interested in forming a relationship with the program, please contact Dr. Hermes. Additionally, any other tools, such as model Argo floats, would also be appreciated.

### Advice on pressure biases in the Argo data set

A part of the global Argo data are subject to biases in reported pressures. These biases are usually less than 5db, but occasionally can be larger (> 20db). These bias errors are being steadily removed by the reprocessing of historical Argo data. We expect that by the end of 2010 these errors will be removed from the global Argo data set in both the delayed-mode and real-time data. Adjusted pressure data are stored in the PRES\_ADJUSTED variable, while the raw biased data remains in the PRES variable.

Normally, Argo pressure data have an accuracy near 2.4db after bias correction. A subset of Argo floats cannot be corrected as the pressure bias was not transmitted by the floats. Within this subset, some will have a high probability of developing large biases. These floats are identified in the delayed-mode processing of Argo data and are flagged with higher pressure errors (20db) in the PRES\_ADJUSTED\_ERROR variable.

For science applications sensitive to small pressure biases (e.g. calculations of global ocean heat content or mixed layer depth) we recommend that:

- Users utilize the quality flags in the Argo data files and data labelled with QC = 1
- Only delayed-mode data are used
- Only ADJUSTED data are used
- PRES\_ADJUSTED\_ERROR be checked and where values are greater than or equal to 20db, these data be rejected

### Update the Argo bibliographies

Please send argo@ucsd.edu citations for Argo articles submitted, in press, or published to keep the bibliographies updated.

### How to Acknowledge Argo Data

The Argo Steering Team encourages the use of a standard acknowledgement in publications that use Argo data: "These data were collected and made freely available by the International Argo Program and the national programs that contribute to it. (www.argo.ucsd.edu, argo.jcom-mops.org). The Argo Program is part of the Global Ocean Observing System". People using Argo float data should, as a courtesy, contact the person responsible for the floats used and outline the type of research or analysis that they intend to carry out.

### Contribute to the next newsletter

If you are doing research on Argo floats that you think others would like to read about, let us know. We are always looking for news article submissions for Argonautics. The research can be on float technology, data assimilation, data analysis methods, or other aspects of Argo data. The next newsletter will be published in summer 2012, so please submit your article idea to argo@ucsd.edu by March 2012. We will let you know soon after if your article idea has been accepted for the upcoming newsletter.

## New dedicated ship for float deployments: meet the *Lady Amber*

Mathieu Belbeoch [belbeoch@jcommops.org]

JCOMMOPS has started to charter a 20m sailing vessel the *Lady Amber*, and its crew, for Argo to help fill gaps in the global array. After a short test cruise in December 2010 between Durban and Cape Town to deploy four floats for CSIRO, and a technical briefing by CSIRO engineers, the team was ready for a larger journey. The *Lady Amber* is currently based in South Africa and contacts have been established with the South African Argo program and other local oceanographers.

The *Lady Amber* can operate anywhere in the world, including high latitudes, with the exception of high piracy zones. There is full flexibility for deployment locations and it could provide a great opportunity for promotional and media activities. The ship can hold 60 floats and has space for 1-4 crew onboard. It is 20kEuro/month or 500 Euro/float if it is full of floats. An overhead is taken for JCOMMOPS to secure the activity on a medium run via a dedicated resource and to cover any extras. The ship can also be used for any other GOOS related activity.

The *Lady Amber* is equipped with an Iridium SBD unit so we can receive launch location acknowledgements and send short updates to the ship by email. It also has an ARGOS/GPS unit so we can track the



racy starts at 10 N.

Several float positions had to be changed to accommodate these restrictions. In addition, since the cruise was delayed for various reasons, the caption suggested going slightly more north for the transect to Perth as the winter season was approaching. Deploying instruments from a sailing vessel can be sporty when the weather is on. One crew member broke her leg during the journey...

At the time of publication, the *Lady Amber* has just arrived in Perth after a successful journey. A few units were not deployed as they failed pre-deployment tests on board. 40 more units are being loaded for a new cruise to Bali, with deployments over the northwest of the Australian Northwest Shelf.

The Argo TC will meet with the crew soon to think about how to sustain this activity in the long run. There are still some practical and legal aspects to strengthen. This adventure is an experiment to see how we can sustain global arrays more efficiently in the future. Many similar opportunities may be available via individual sailors, NGOs, sailing races, etc. A dedicated position is being established at JCOMMOPS to coordinate this and facilitate the daily work of oceanographers and marine meteorologists.

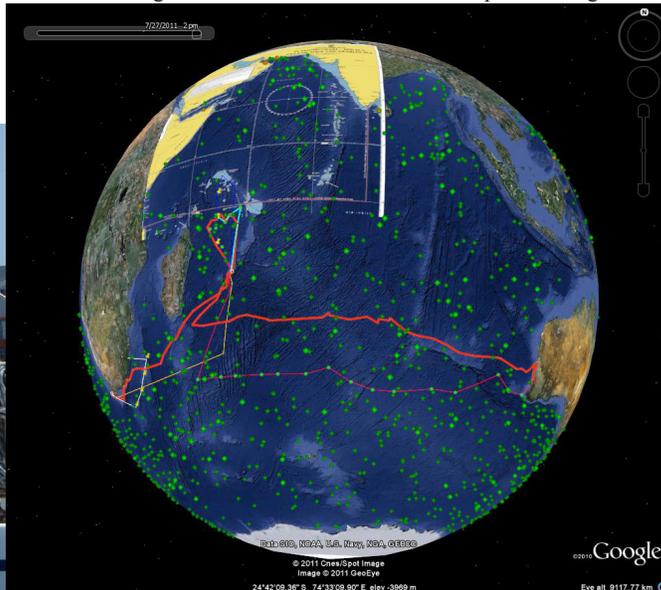
"I thank the CSIRO for having taken the risk of funding this experiment, and the *Lady Amber* crew for its full dedication, with already 5 months at sea for Argo in sometimes rough conditions," says the Argo TC. Contact the Argo TC for more information on ship chartering.



ship in real-time and the crew have an alarm button in case of problems. (Add [http://argo.jcommops.org/FTPRoot/JCOMMOPS/Cruises/JCOMMOPS\\_ZR2335.kml](http://argo.jcommops.org/FTPRoot/JCOMMOPS/Cruises/JCOMMOPS_ZR2335.kml) on "track in real time").

The first real cruise, chartered for Australian Argo via JCOMMOPS,

was originally planned to deploy about 20 floats from Cape Town to Mauritius, then from Mauritius to Seychelles, then back to the south of Mauritius to transect to Perth at 35 S. The ship will also service two RAMA moorings. The transect to Seychelles was restricted for security reasons; the risk of pi-



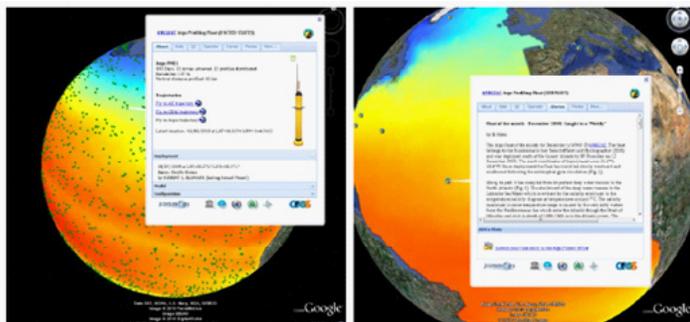
All photos are courtesy of Alan Poole from CSIRO

Google Earth cruise track courtesy of Argo TC

## Argo and Google Earth: let the exploring begin

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The Argo TC has coordinated work done within JCOMMOPS, with Scripps colleagues (M. Scanderbeg, S. Diggs, J. Gilson) and with JAMSTEC on the Argo layers for Google Earth. S. Diggs began pushing Argo to use a web based interface such as Google Earth to promote ocean observations, and specifically Argo, to the larger public after developing a partnership between Scripps and Google.



The Argo layers application is ideal for network tracking, promotion and demonstration to a larger public. It is also used extensively by the Argonauts to retrieve beached floats, plan their deployments, relay feedback on data QC, etc. In addition the application provides access to Argo data from the Global Argo Marine Atlas (data source: 100% Argo data, Roemmich and Gilson, 2009) with temperature, salinity, steric height and anomalies layers, over ten depth levels since 2004.

When you click on a float, a window pops up with information about the float including technical data, profile data and trajectory information. It is possible to see delayed mode quality control information on many floats. You can download data from the float by clicking a link. When you click the "Fly to trajectory" link, the observation locations are plotted with the float's trajectory, and it is possible to download the data for individual profiles thanks to a partnership with JAMSTEC. All these features make it possible to learn a lot about single floats while the overlays of temperature, salinity and steric height help give a picture of the entire Argo array.

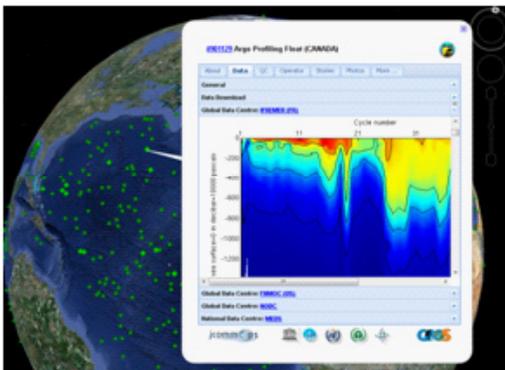
Besides assembling all the web tools (made by Argo PIs, agencies, global/regional data centres) available for floats and related observations on the web, the layer provides a set of "float stories", forming gradually a rich educational content. Some "climate change" oriented stories could also be added along the T/S/SH layers and the application could be linked with things such as the OOPC ocean climate indices. There is room for this to grow and any collaboration would be welcomed.

Following an IOC/GOOS initiative, the BBC World News has set up a 30 minute movie to tell the story of GOOS and Argo in particular. The movie includes sequences in Hobart (CSIRO, with S. Wijffels as "earth reporter" and movie focal point), Toulouse (JCOMMOPS office, Argo TC, and a duplex with Hobart), and Buenos Aires (AST meeting 2011, key AST members). This is a great promotional material for GOOS and Argo. The Google Earth displays were used throughout in the movie. The BBC movie is at <http://www.open.ac.uk/openlearn/whats-on/earth-reporters-sea-change>

<http://argo.jcommops.org/argo.kml>

see demo videos at:

<http://w3.jcommops.org/FTPRoot/Argo/TMP/Google>



These results were generally consistent for Aanderaa Optodes deployed throughout the world ocean.

While the Optode stability is attractive, measurement errors of the order of 12  $\mu\text{mol/kg}$  are unacceptable in most quantitative biogeochemical studies. Meeting participants agreed that errors in oxygen of 1  $\mu\text{mol/kg}$  or less should be the goal of any float-based measurement program. While this would seem to be a difficult goal, there was a general consensus that several steps could be taken immediately to reduce the present errors significantly and to move towards an accuracy of 1  $\mu\text{mol/kg}$ . These steps are summarized here:

- (1) Calibrate all Optode sensors to an accuracy of 1  $\mu\text{mol/kg}$  in a laboratory setting prior to deployment.
- (2) Collect concomitant Winkler oxygen samples at float deployments whenever possible.
- (3) Decrease the response time of the sensor (presently near 30 seconds) without sacrificing accuracy.
- (4) Explore methods to use the temperature from the CTD unit on the float in the Optode oxygen calculation instead of the temperature sensor on the Optode. This should help to mitigate the known thermal mass effect caused by the Optode's relatively slow temperature sensor.
- (5) Transmit the raw data from the Optode (i.e., B-phase data) instead of computed oxygen values. This will make it easier to adjust the data and explore new calibration methods once the float has been deployed.
- (6) Employ a new calibration equation based on the physics of the oxygen-sensing process (the Stern-Volmer equation) instead of the arbitrary polynomial now used.
- (7) Continue to explore issues such as self-heating and sunlight bleaching of Optode sensors.

It was noted that there are two other potential oxygen sensors for floats that have yet to be examined by the Argo community. The first, the Rinko Infinity sensor, is an optical device that operates on the same principle as the Optode and appears to have a response time much faster than the Aanderaa sensor, although there is little experience with this product. The second sensor, the SeaBird 63 IDO, is another optical device that will become available later in 2011 and promises to address issues (1), (3), (5), and (6) in the list above. SeaBird suggests a long-term accuracy of 1  $\mu\text{mol/kg}$  for the 63 IDO, which should serve the Argo community well if realized.

The participants in the meeting generally concluded that we are on the verge of being able to make useful, stable, long-term measurements of dissolved oxygen from profiling floats, with the goal of an accuracy of 1  $\mu\text{mol/kg}$  very possibly attainable in a few years. Even with present limitations, the float-based oxygen data are valuable, and there was a consensus that we should continue to equip as many Argo floats as possible with dissolved oxygen sensors. In the future it is likely that success in measuring dissolved oxygen and other biogeochemical parameters from profiling floats will lead to further discussions about the expansion of Argo's core mission or, alternatively, to new float-based observing programs dedicated to making these important observations.

Proceedings and presentations from the workshop can be found at [http://wwz.ifremer.fr/lpo\\_eng/SO-Argo-France/Argo-oxygen-meeting](http://wwz.ifremer.fr/lpo_eng/SO-Argo-France/Argo-oxygen-meeting). A full meeting report should be available soon.

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