Previous Argo Workshops:

Results and Recommendations

Stephen C. Riser
University of Washington

ARVOR-PROVOR Technical Workshop
Brest, France
28 January 2020

The Original Argo Implementation Plan (1998)

On The Design and Implementation of Argo

A Global Array of Profiling Floats

The Argo Science Team[1]

[1] Dean Roemmich (chair), Olaf Boebel, Howard Freeland, Brian King, Pierre-Yves LeTraon, Robert Molinari, W. Brechner Owens, Stephen Riser, Uwe Send, Kensuke Takeuchi, Susan Wijffels.

Preface

This document describes some initial ideas for the design and implementation of *Argo*, a global array of autonomous profiling floats. The original concept grew out of two independent, but connected, initiatives, "*A Proposal for Global Ocean Observations for Climate: the Array for Real-time Geostrophic Oceanography*" (ARGO), by Dean Roemmich, and "*A program for Global Ocean SAlinity MonitORing*" (GOSAMOR), by Ray Schmitt. Early in 1998 the International Steering Team for GODAE (the Global Ocean Data Assimilation Experiment) endorsed the broad concept of such an array and undertook to develop a plan. In the 2nd quarter of 1998 the Upper Ocean Panel of CLIVAR also considered these proposals and unanimously agreed that such an initiative must be given high priority in the CLIVAR Implementation plans.

In July of 1998 a Workshop was held in Tokyo to discuss the prospects for *Argo* and an initial outline for a plan was drawn up. At that Workshop, which was jointly convened by GODAE and the CLIVAR UOP, an *Argo* Science Team was appointed with the charge to produce an initial design and implementation plan. The present document is the response to that charge.

An initial draft of this document was widely circulated through the oceanographic and climate community for review. This review drew many comments and suggestions and raised a number of significant issues. Because of time constraints, and the need to have a document available for the CLIVAR Conference in December of 1998, we, as Chairs of the convening bodies, decided that a detailed revision was not wise, and probably not possible, on this time frame. Many of the issues require detailed scientific study and need some time for fuller consideration. As an interim measure, we have attended to a few of the more pressing issues, and prepared a consolidated list of issues and items for consideration by the Science Team at a later time.

This document then represents an initial set of ideas for the design and implementation of *Argo*, and presents the scientific rationale for proceeding with *Argo*. We think you will find the case for *Argo* a strong one, and that the initiative, though ambitious, both doable and worth doing.

We thank the *Argo* Science Team, and other contributors, for this paper, and look forward to the early development of a more detailed design and complete implementation plan.

Neville Smith
Chair of the International GODAE Steering Team

and

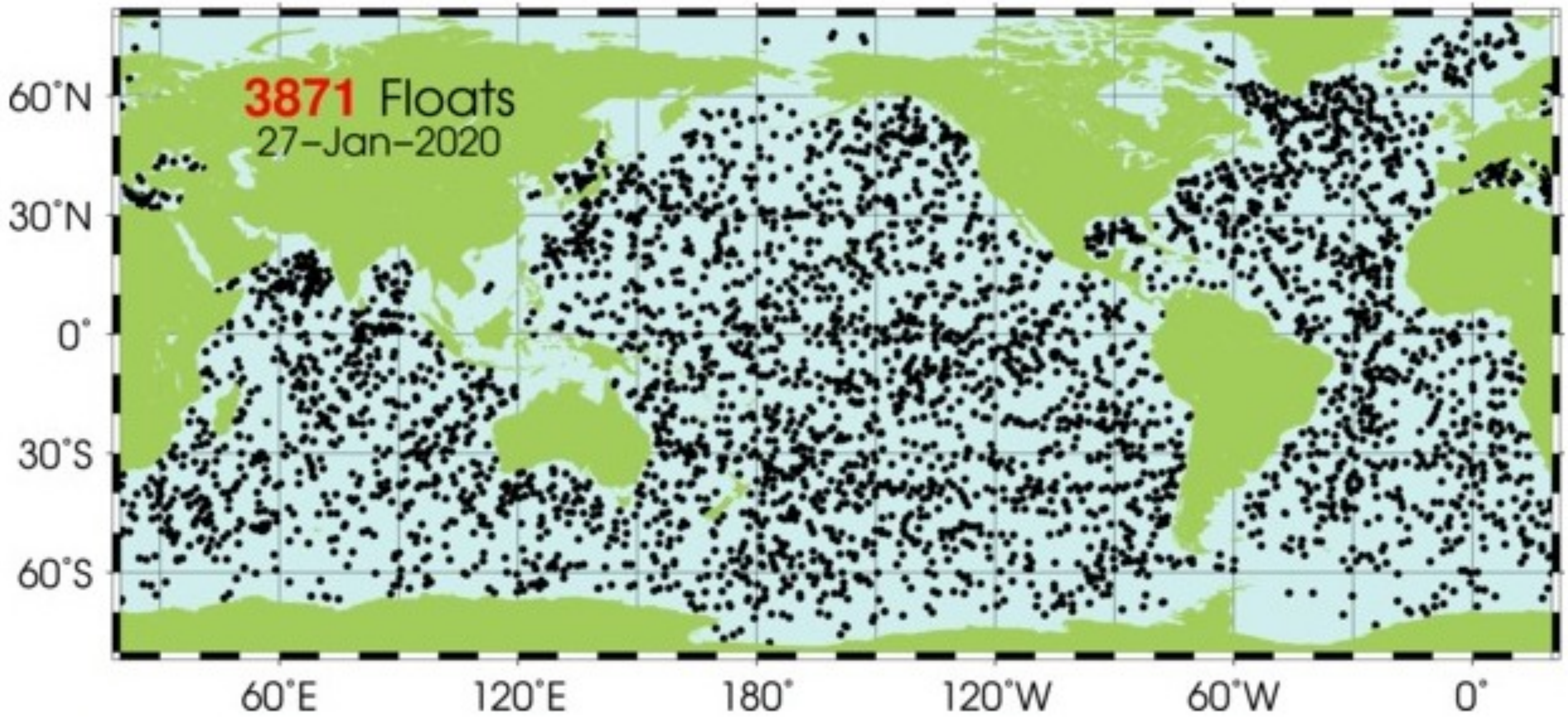
Chet Koblinsky
Chair of the CLIVAR Upper Ocean Panel

Argo was conceived as a program to:

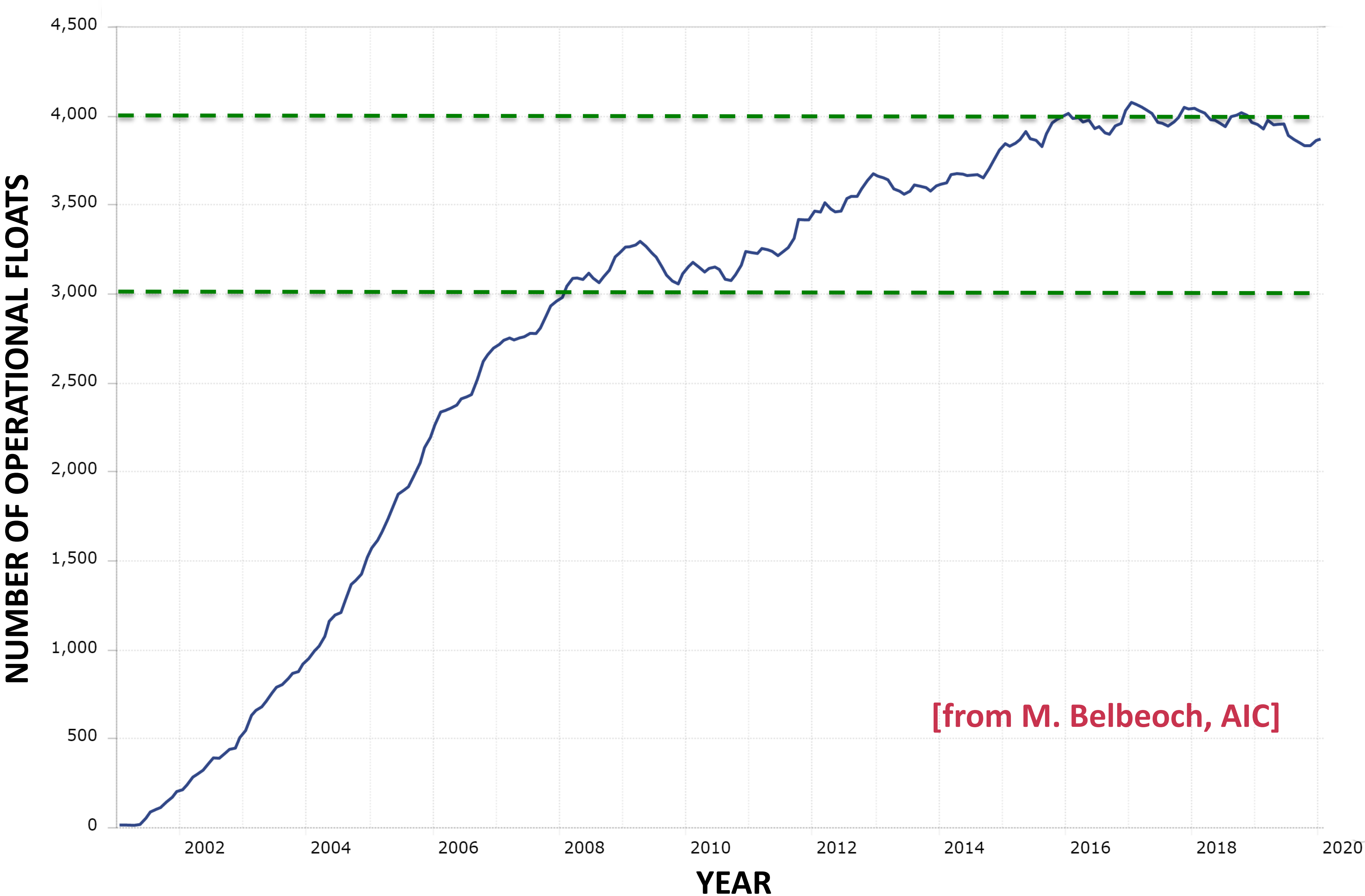
- Sample the ocean globally using profiling floats
- Examine the climate scale of variability (≥ 10^3 km, ≥ monthly)
- 200-300 km horizontal resolution
- Sample as deep as possible (2000 m)
- Examine changes in the heat and freshwater content the ocean
- Make the data collected publicly available in near real-time
- Work with other elements of the climate observing system

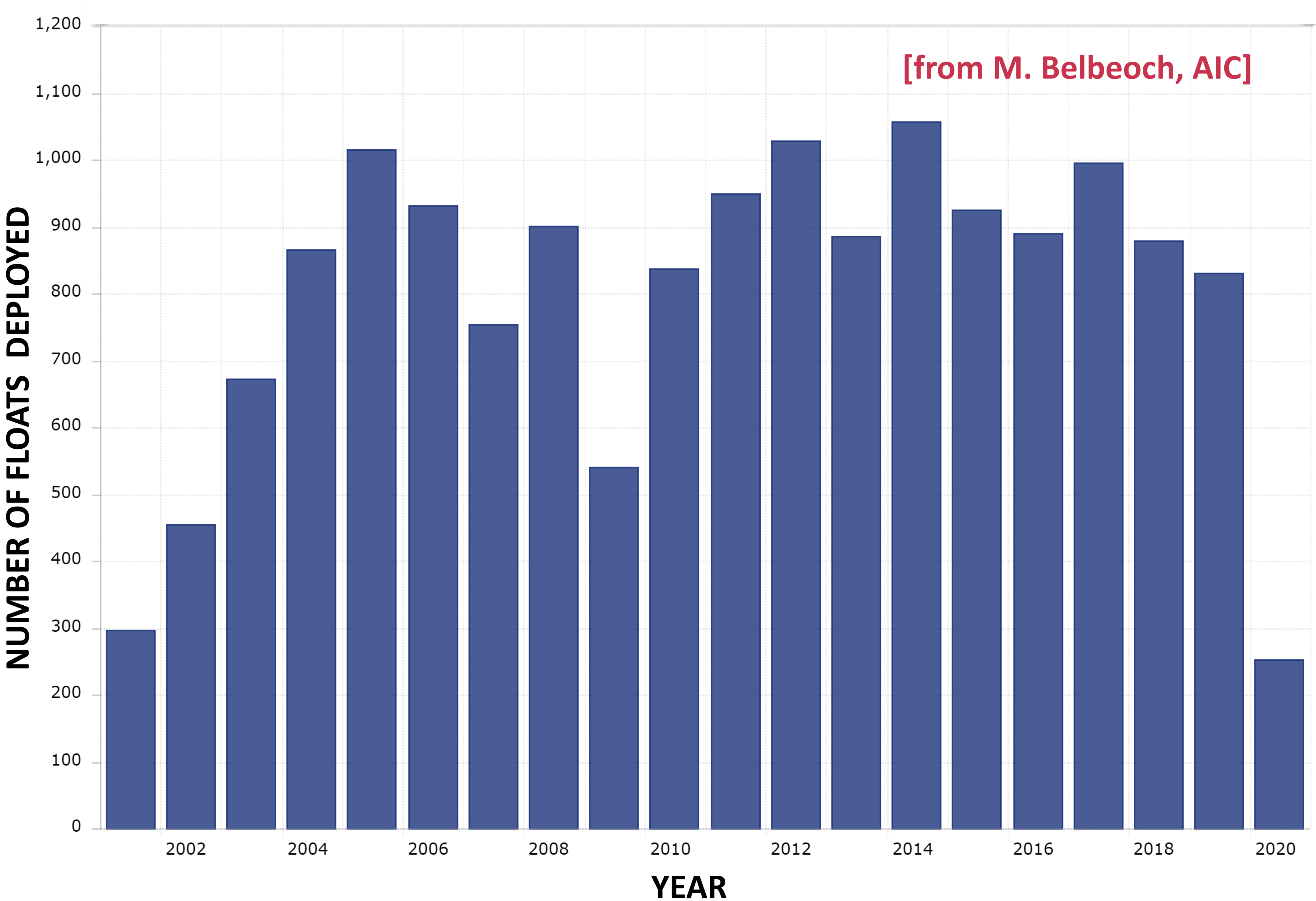
A program to address these questions would likely require:

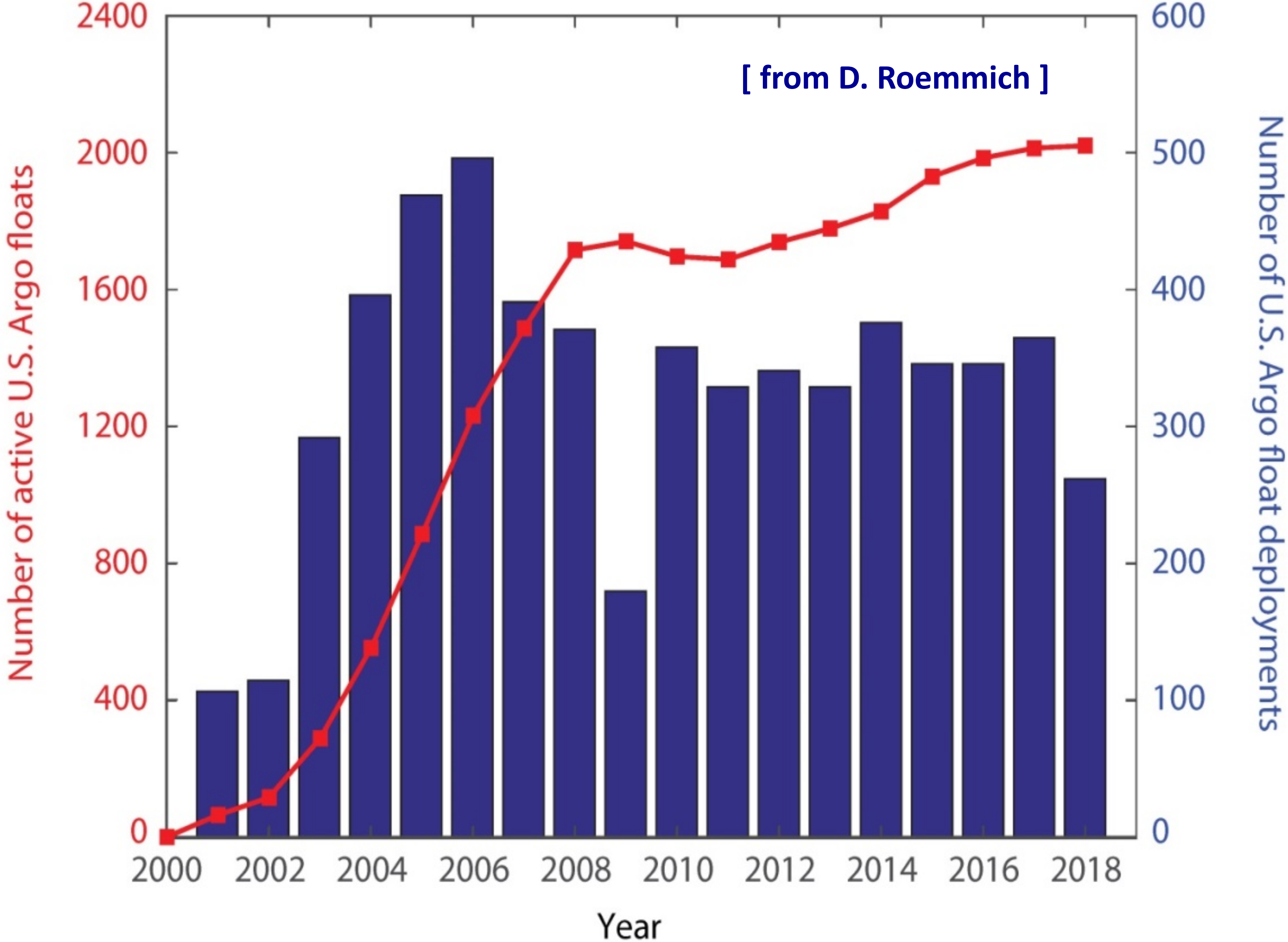
- A global array of roughly 3000 floats
- Float lifetimes > 3 years (≈ 100 profiles)
- *T*, *S*, and *p* observations of sufficient accuracy and precision
- A data system capable of both real-time and delayed-mode editing



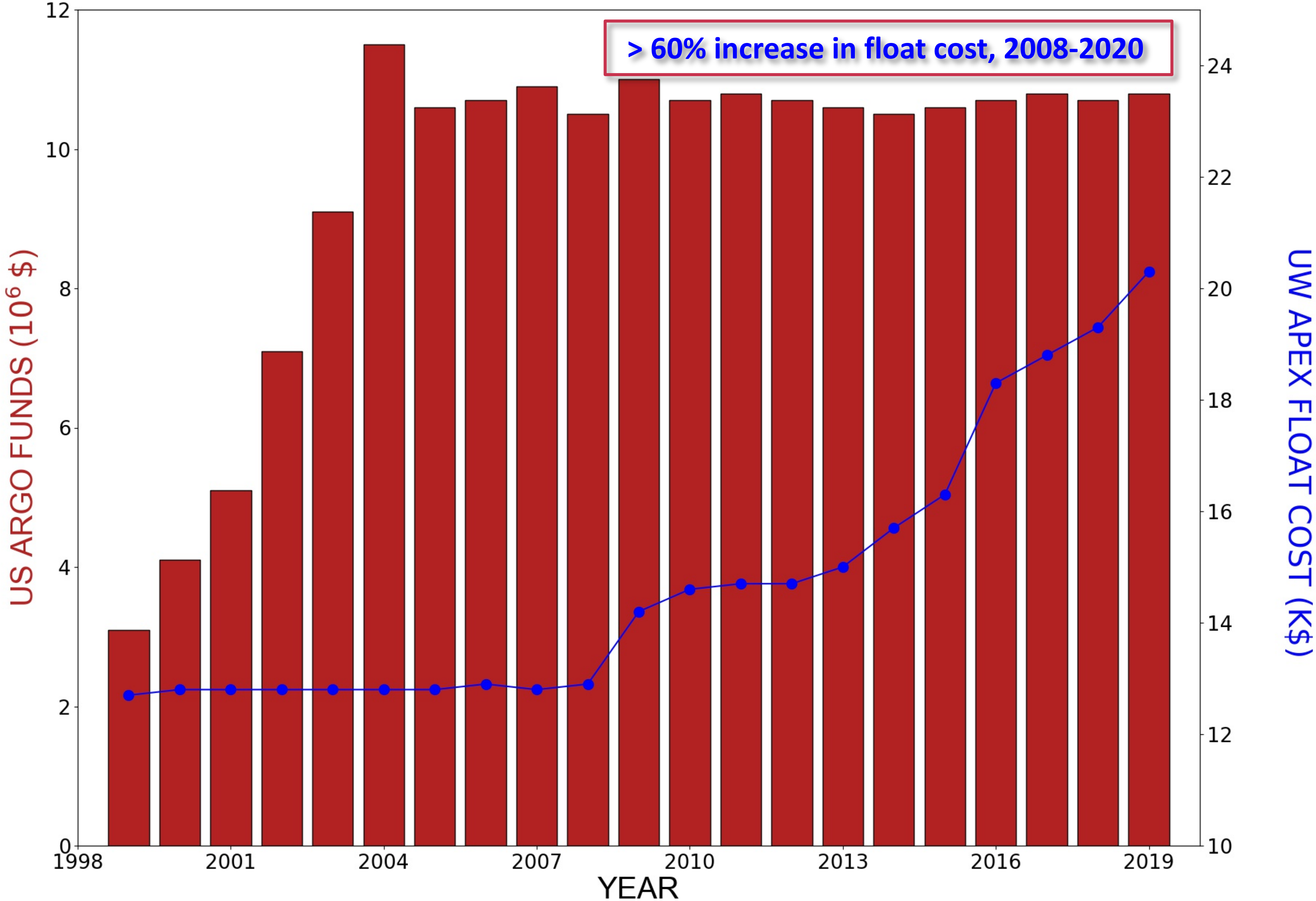
http://www.argo.ucsd.edu/


4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
NUMBER OF OPERATIONAL FLOATS
YEAR
[from M. Belbeoch, AIC]

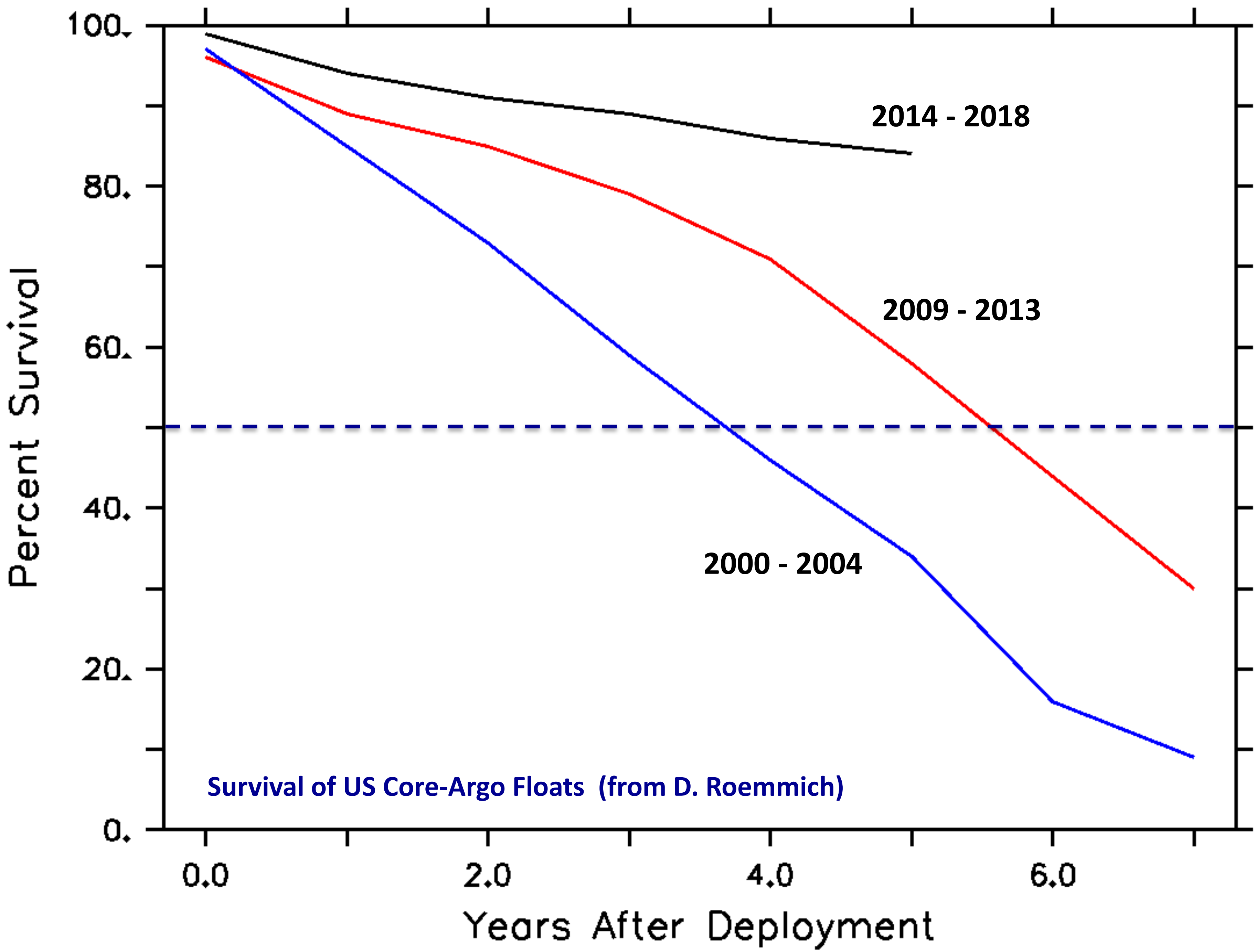

[from M. Belbeoch, AIC]
NUMBER OF FLOATS DEPLOYED
0
100
200
300
400
500
600
700
800
900
1,000
1,100
1,200
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
YEAR



[from D. Roemmich]
Number of active U.S. Argo floats
Number of U.S. Argo float deployments
Year
0
400
800
1200
1600
2000
2400
0
100
200
300
400
500
600
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018

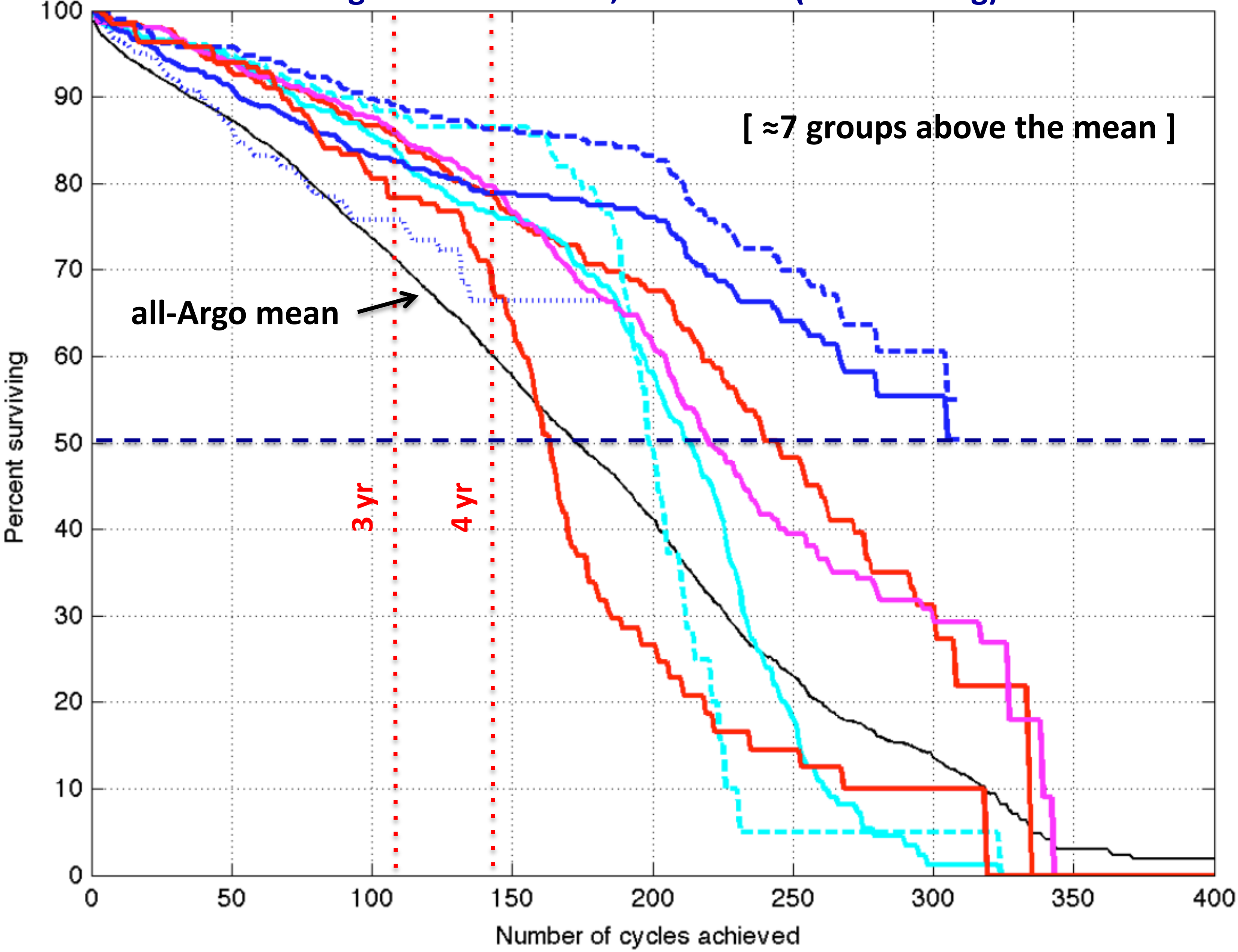


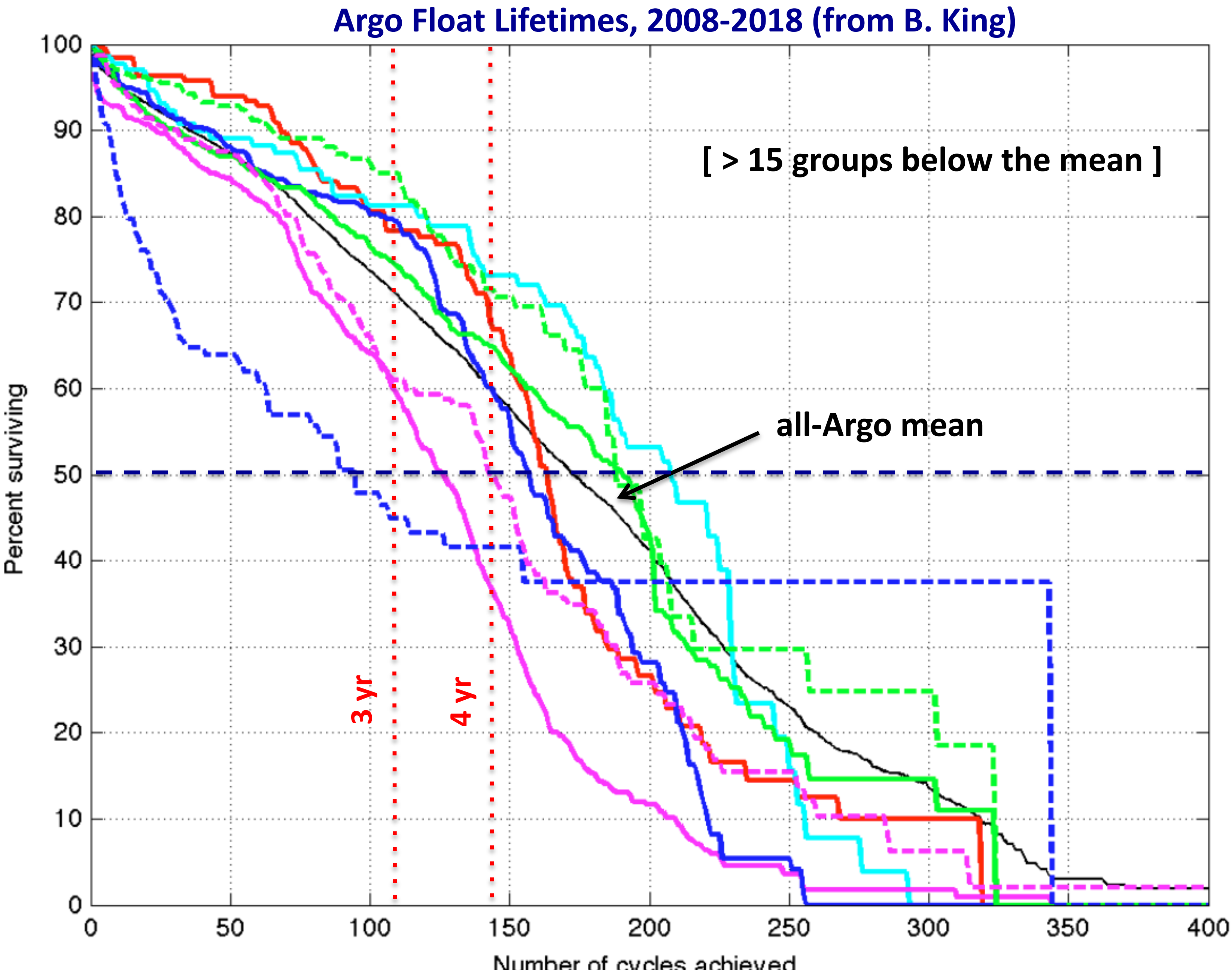
> 60% increase in float cost, 2008-2020
US ARGO FUNDS (10^6 $)
UW APEX FLOAT COST (K$)
YEAR
0
2
4
6
8
10
12
10
12
14
16
18
20
22
24
1998
2001
2004
2007
2010
2013
2016
2019



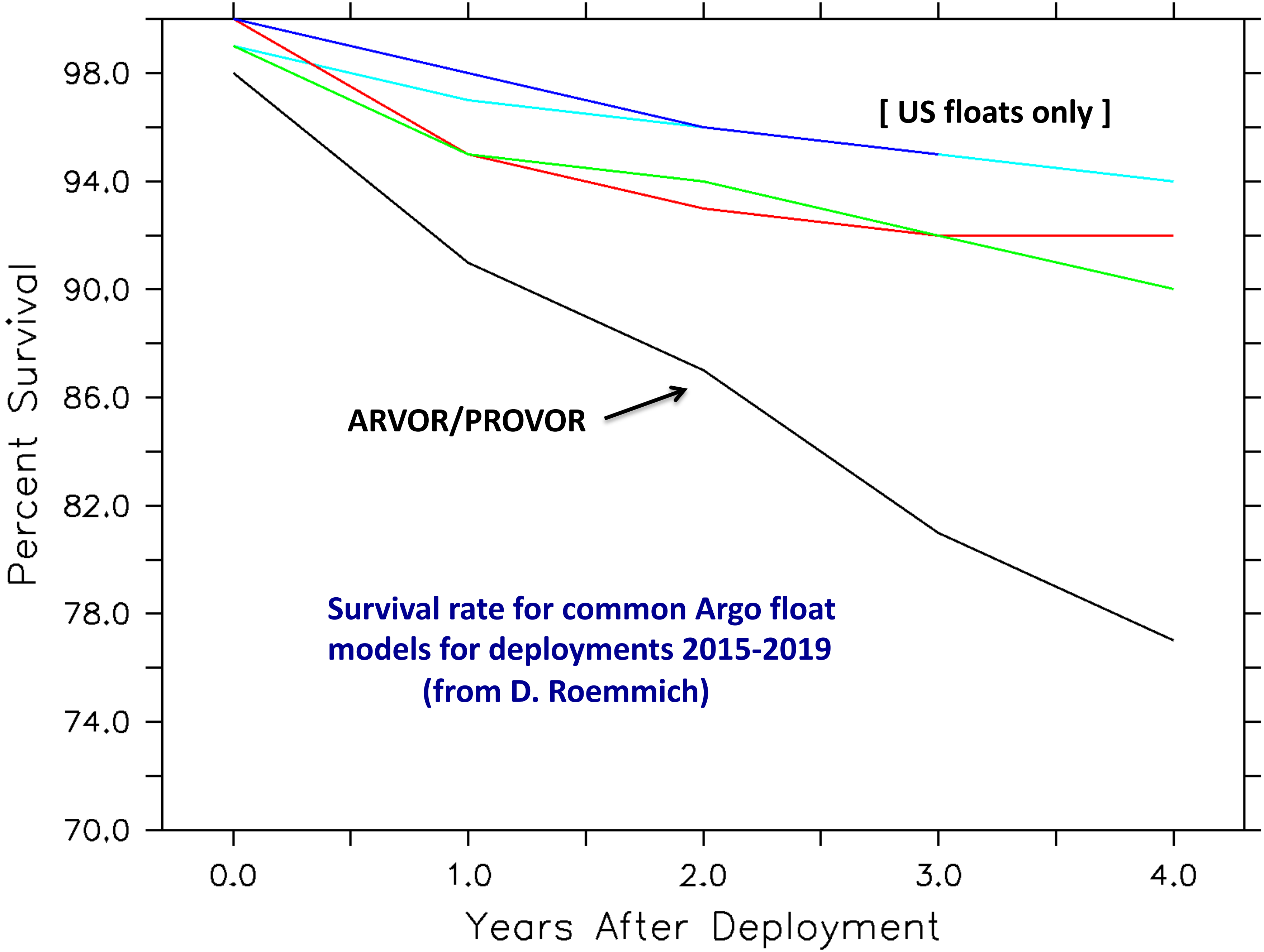
100.
80.
60.
40.
20.
0.
Percent Survival
0.0
2.0
4.0
6.0
Years After Deployment
2014 - 2018
2009 - 2013
2000 - 2004
Survival of US Core-Argo Floats (from D. Roemmich)

Argo Float Lifetimes, 2008-2018 (from B. King)





Argo Float Lifetimes, 2008-2018 (from B. King)
[> 15 groups below the mean]
all-Argo mean
3 yr
4 yr
Percent surviving
Number of cycles achieved
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300
350
400

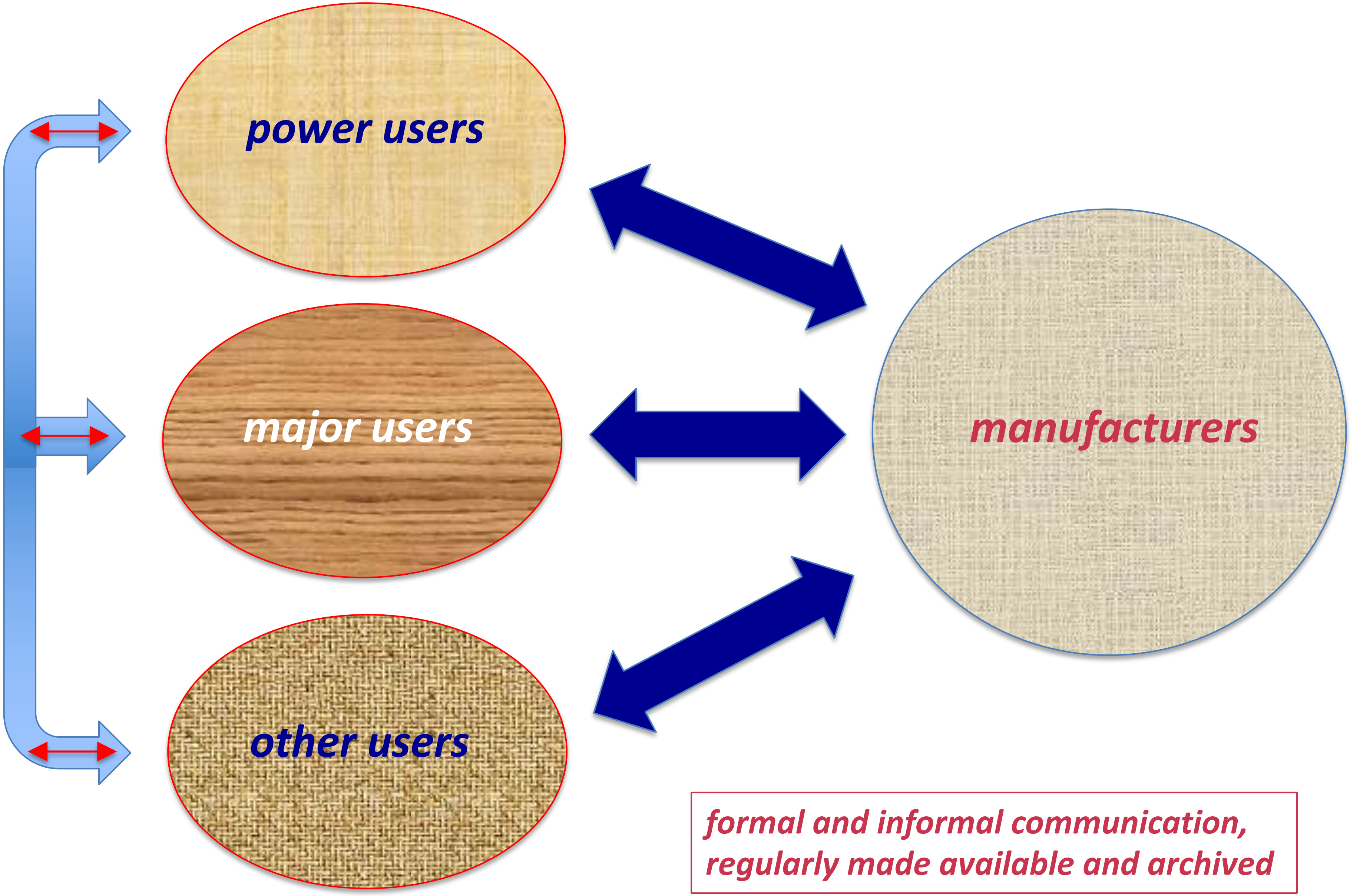


[US floats only]
ARVOR/PROVOR
Survival rate for common Argo float
models for deployments 2015-2019
(from D. Roemmich)
Percent Survival
98.0
94.0
90.0
86.0
82.0
78.0
74.0
70.0
0.0
1.0
2.0
3.0
4.0
Years After Deployment

A major goal of this workshop (as it was for previous ones) should be to take the necessary steps to improve the mean lifetime of the floats. This can be done by:

(1) Identifying the common failure modes (in this case, for NKE Arvor/Provor)
(2) Communicating these results to the manufacturer (if not already done)
(3) Having the more successful groups work with the other groups to improve float performance

[Each of these steps involves improved communication]


power users
major users
other users
manufacturers
formal and informal communication,
regularly made available and archived

Results from Previous Workshops

- **1st Argo Technical Workshop (UW Seattle, 2005)**

→ A goal of 4 year lifetimes for all APEX floats
→ Use of lithium batteries is encouraged (the simplest way to increase float lifetime)
→ Recovery of floats for CTD recalibration is encouraged whenever possible
→ Create a single clearinghouse for analysis of APEX engineering data across programs

- **Float and CTD Technical Workshop (UW Seattle, 2017)**

→ Manufacturers should provide simple tools for acceptance testing of floats by users
→ Users should carefully provide feedback to manufacturers about float performance
→ Floats should be tested by users to the maximum extent possible prior to deployment
→ Assess the performance of various types of lithium batteries in each float model
→ Encourage the development and testing of alternative type of CTDs (i.e., RBR)

- **BGC Profiling Float Workshop (UW Seattle, 2018)**

→ Create a relatively simple path for new groups to use BGC-Argo floats
→ *Vigilance*: sensor performance must be monitored very closely, in near real-time
→ Continue to design and update the BGC Argo data system
→ Add O_2 sensors to core-Argo floats whenever possible
→ Encourage new and novel sensor development
→ Recognize that BGC studies can take many forms (similar to Argo, or not)
→ Increased communication between all parties involved

Testing of Floats Prior to Deployment

Sample of engineering data from a UW APEX float checked in the UW float laboratory and also dockside prior to deployment

```
APEX version 081119  sn 18082
User: f18082
Pwd:  0xafb3
Pri:  AT+CBST=71,0,1;DT0088160000510          Mhp
Alt:  ATDT0012066163256                       Mha
ISUS: Enable sampling.                        Me
DURA: Enable sampling.                        Md
ENABLE DURA reference battery power.          Ma
ENABLE FLBB sample mode.                      Ms
INACTV ToD for down-time expiration. (Minutes)    Mtc
 14400 Down time. (Minutes)                   Mtd
 00660 Up time. (Minutes)                     Mtu
 00540 Ascent time-out. (Minutes)             Mta
 00240 Deep-profile descent time. (Minutes)   Mtj
 00240 Park descent time. (Minutes)           Mtk
 00002 Mission prelude. (Minutes)             Mtp
 00015 Telemetry retry interval. (Minutes)    Mhr
 00060 Host-connect time-out. (Seconds)       Mht
 00080 ZModem time-out. (Seconds)             Mhz
   985 Continuous profile activation. (Decibars)  Mc
  1000 Park pressure. (Decibars)              Mk
  2020 Deep-profile pressure. (Decibars)      Mj
   066 Park piston position. (Counts)         Mbp
   016 Deep-profile piston position. (Counts) Mbj
   010 Ascent buoyancy nudge. (Counts)        Mbn
   022 Initial buoyancy nudge. (Counts)       Mbi
   001 Park-n-profile cycle length.           Mn
  50.0 Ice detection: Mixed-layer Pmax (Decibars)  Mix
  20.0 Ice detection: Mixed-layer Pmin (Decibars)  Min
 -1.78 Ice detection: Mixed-layer Tcritical (C)    Mit
 0xffd Ice detection: Winter months [DNOSAJJMAMFJ] Mib
   155 Maximum air bladder pressure. (Counts) Mfb
   237 OK vacuum threshold. (Counts)          Mfv
   231 Piston full extension. (Counts)        Mff
   016 P-Activation piston position. (Counts) Mfs
     2 Logging verbosity. [0-5]               D
  0002 DebugBits.                             D
  04ab Mission signature (hex).
> c Battery [221cnt, 15.5V]  Current [  3cnt, 10.2mA]  Barometer [213cnt,  12.5psi]  Pneumometer [107cnt,  12.5psi]
> c Battery [221cnt, 15.5V]  Current [  3cnt, 10.2mA]  Barometer [213cnt,  12.5psi]  Pneumometer [107cnt,  12.5psi]
> t
```

***Note*:**

A typical factory-supplied APEX float for Argo costs $20K and will last for 150 profiles (the Argo average), for a cost-per-profile of $133.

UW does fabrication and pre-deployment testing costing and additional $4K.   This typically results in an addition of 100 profiles to the life of the float, lowering the cost per profile to $100.

[plus: detailed checks of all sensors, CTD, GPS, Iridium, bladders, air pump]

Navis float deployer interface-- connecting

SeaBird Electronics has built a test device that can be used for pre-deployment testing of SBE CTD units and Navis floats by any float group.

The test unit straps onto a float in a laboratory and is electronically connected to the float.   The float user initiates a test sequence by simply pressing a button on the test device.   The test device will then initiate as series of tests that require 15-20 minutes. At the end of the tests the user will get a log of the results and a confirmation (or not) that the float is ready to deploy.

Strap device to float using velcro strap
Align arrow with round anode

Float must be standing upright for testing!
if float is on its side, this testing can cause a lock-up which will permanently disable the float.

Avoid static discharge to hexagonal pressure port-
touch float hull, then clip black lead to the round anode then clip yellow lead to the hexagonal pressure port

Optional--
Connect to a terminal program (such as hyperterm)
plug USB into a computer to see a display of the tests
when connect to computer, yellow light displays to show device is connected/charging.
DO NOT INPUT KEYSTROKES! Commands entered can accidentally disable float

This cost of this simple test device is not high, and it has been shown to work well in diagnosing floats that have some problem prior to deployment. Such floats can either undergo further testing and possible repair or be returned to the manufacturer. In many cases this has saved a float from failure prior to deployment.

The performance statistics of SeaBird floats has increased substantially since this device was first made available.

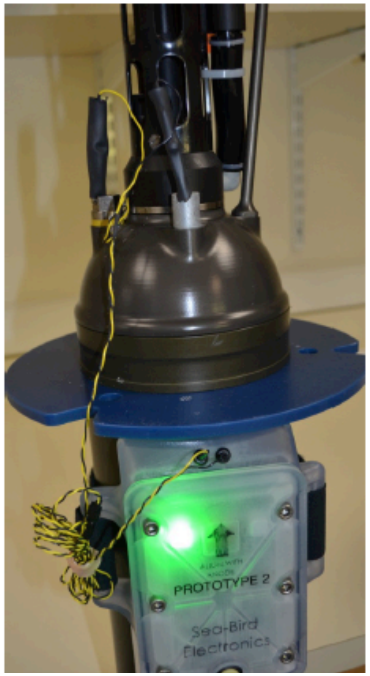
Navis float deployer interface-- test

To start test, push button
this will be acknowledged by a flash of the red and green lights.
Test will take approximately 4 minutes to run.

While running, the lights will alternate between red and green. If optional computer is connected, it will display the tests that are running.

When test completes, it will show steady green light if successful, red light if failed.

Acknowledge the result by pushing the button once and disconnect the device. If successful, deploy the float.
Be sure to disconnect device from float before deployment!



Testing New CTDs (RBR)

For several years, the prototype testing of RBR CTD units on Argo floats has been encouraged by the Argo Steering Team.

At some point in the future the AST would like to be able to recommend the RBR unit as an acceptable CTD that is interchangeable in climate studies with the SBE-41 CTD that has been used by Argo since its beginning.

Having 2 acceptable types of CTDs would be an important advance for Argo and ocean research in general.

Competition and Multiple Sources of Equipment are Desirable

Float Batteries: An Important Factor in Increasing Lifetimes

- **Floats used in US Argo have used 100% lithium batteries since 2006**
- **Li batteries should be used in all floats, as alkaline batteries cannot provide long enough lifetimes**
- **There are several kinds of Li batteries used in US floats (APEX, NAVIS: Electrochem; SOLO-2: Tadiran)**
- **Passivation can be a problem with the use of Li batteries and needs to be assessed for each type of float (more serious with SOLO-2, hence the switch to Tadiran batteries)**
- **Tadiran batteries are hybrid batteries that contain rechargeable secondary cells. These cells do not exhibit passivation, allowing them to function during high current periods when the buoyancy pump is turned on. This has been proven to be very useful for increasing longevity in SOLO-2 floats.**

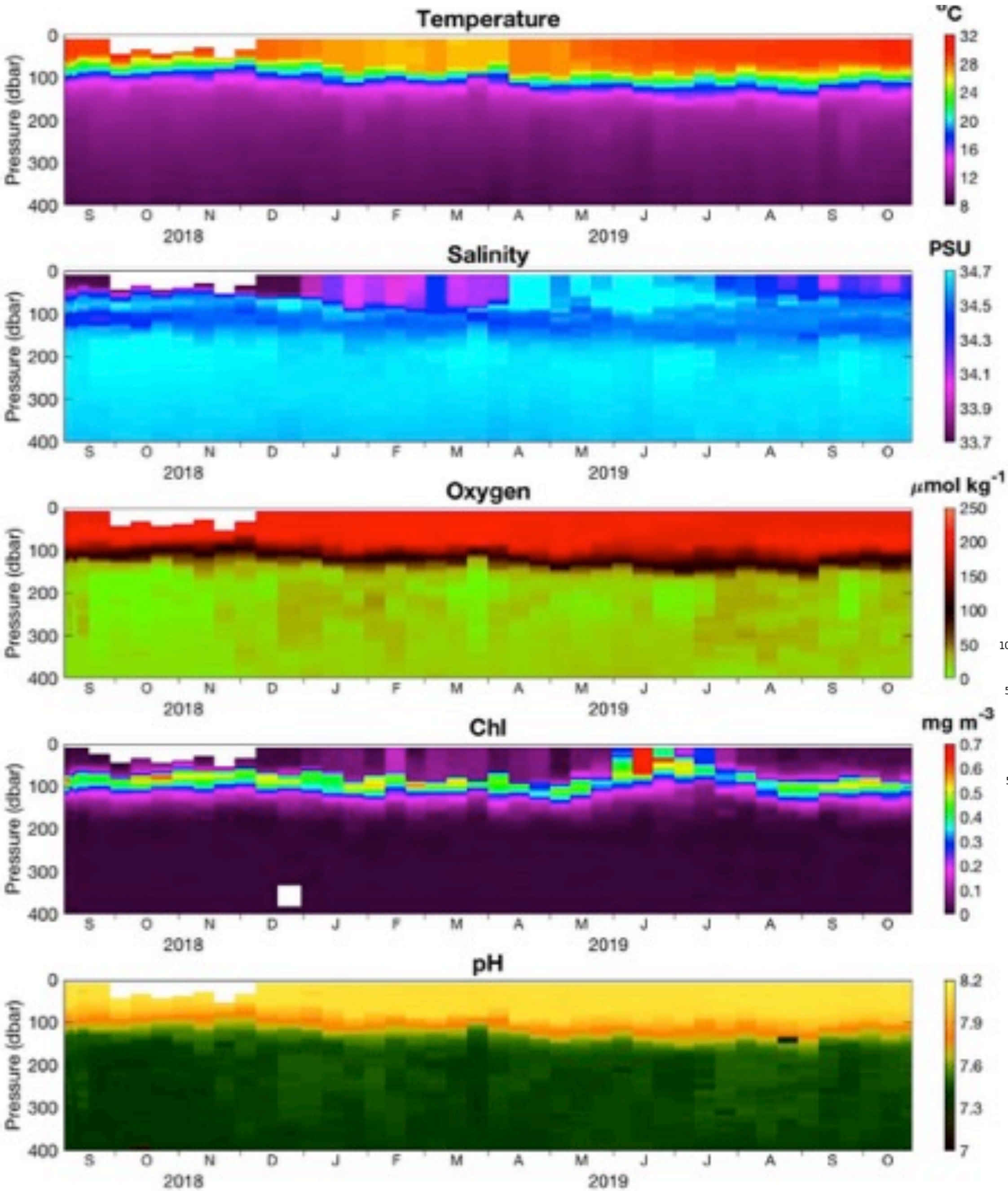
Battery passivation: Passivation consists of a very thin, high resistant, self-assembled LiCl layer formed on the surface of the lithium battery anode. It is formed as a result of a chemical reaction between the battery electrolyte and the lithium anode. Without the passivation layer, lithium batteries would not be viable, because the lithium would discharge and degrade quite rapidly. An advantage of the passivation layer is it allows the battery to have a very low self-discharge rate and long shelf life. When this layer grows too thick, however, battery performance is affected. When batteries have not been used for an extended period (10 days in Argo floats), a passivated cell may exhibit voltage delay, which is the time lag that occurs between the application of a load on the cell and the voltage response. This effect might be severe and degrade the batteries when the buoyancy pump is turned on after a period of 10 days, effectively reducing battery efficiency.

Best Practices in the Use of BGC Profiling Floats

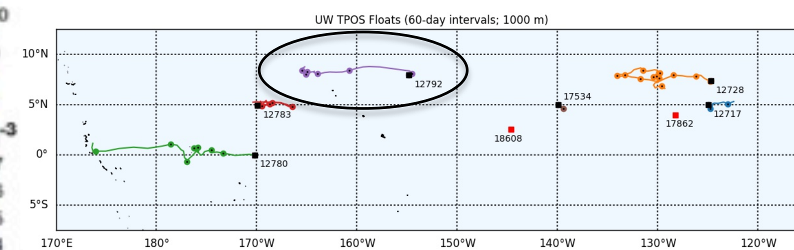
- → BGC floats are more complicated than core-Argo floats and require additional care
- → Experienced users should help newer users to become more knowledgeable
- → Care needs to be taken in sensor calibration and adjustment after deployment
- → Introduce new sensors slowly; understand their characteristics before mass deployments
- → Many BGC float users will not be part of Argo, resulting in new mission parameters
- → Floats in BGC-Argo are Argo floats, and should have missions consistent with core-Argo
- → Hold manufacturers accountable; improve communication about strengths and weaknesses
- → Data management requires considerable attention beyond what is done in core-Argo
- → All groups need to work together to populate the world ocean with BGC-floats

A new prototype BGC float

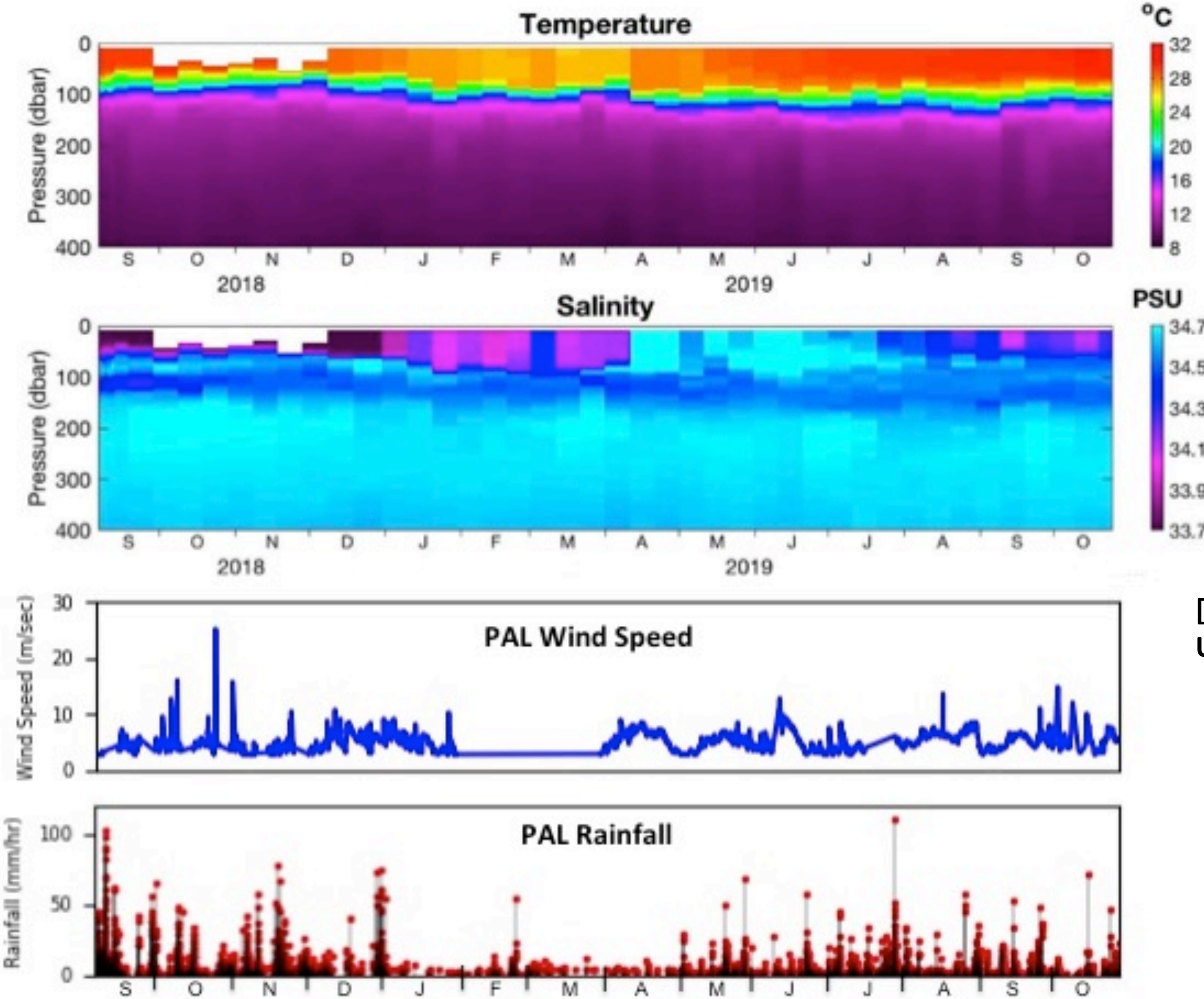
Float Technology: Continued Advancements



CTD and BGC variables from UW float 12792, 9/2018-10/2019 in the Equatorial Pacific



[CTD ; O_2 ; FLBB ; pH ; wind/rain]



[All data from UW float 12792]

TPOS floats measure wind speed and rainfall using a Passive Acoustic Listener (PAL) at intervals of 1 hr while parked at 1000 m during their drift phase. Winds and rain are weakest Jan-Apr, resulting in lower surface salinities.

Summary

1. The key to long-term success in Argo and with profiling floats in general is to increase the average float lifetimes.

2. The surest way to improve the lifetime of floats is to encourage constant and detailed communication between float users and float manufacturers.

3. Users should consult with each other about successes and problems, with periodic workshops held to summarize findings.

4. Successful use of profiling floats requires constant vigilance: detailed checking before and after deployment.

5. New technology is essential for progress, but should be tested extensively before deploying new floats or sensors in large numbers.