WORLD METEOROLOGICAL ORGANIZATION

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION (OF UNESCO)

DATA BUOY COOPERATION PANEL

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REPORT BY THE TASK TEAM ON INSTRUMENT BEST PRACTICES AND DRIFTER TECHNOLOGY DEVELOPMENTS(TT-IBPD)

(Submitted by Richard Crout, TT Interim Co-Chair, USA)

Summary and purpose of the document

This document contains the report by the chairperson of the DBCP Task Team on Instrument Best Practices and Drifter Technology Development.

ACTION PROPOSED

The Panel will review the information contained in this report and comment and make decisions or recommendations as appropriate. See part A for the details of recommended actions.

Appendices: A. Report by the Task Team on Instrument Best Practices and Drifter Technology Development

B. Terms of Reference of the DBCP Task Team on Instrument Best Practices and Drifter Technology Development

-A- DRAFT TEXT FOR INCLUSION IN THE FINAL REPORT

6.2.1 Mr Richard Crout (USA), interim co-Chairperson of the Task Team on Instrument Best Practices and Drifter Technology Development (TT-IBP), reported on the progress during the intersessional period. The Panel noted that he had been nominated to act as interim co-Chairperson following the resignation of Dr Bill Burnett (USA) as Chair of the Team. The Panel used that opportunity to thank Bill Burnett for his contributions in the past years to the work of the Task Team, and wished him every success in his new position.

6.2.2 Mr Crout particularly reported on the outcome of evaluation studies conducted by (i) the Global Drifter Program and its Data Assembly Center at AOML, (ii) the UK Metoffice, (iii) Météo France, (iv) Environment Canada, and (v) the Marine Hydrophysical Institute of Ukraine and Marlin-Yug Ltd. In particular, the following findings were reported:

1. Battery problems with Clearwater and recent Technocean drifters, and manufacturing problems with Technocean drifters, have greatly reduced their lifetimes. More recent problems were found in Pacific Gyre and Clearwater PMT-bearing drifters operating in PTT mode, where higher power consumption was inferred from abbreviated lifetimes (typically ~180 days).
2. Per a GDP study on re-evaluation of drogue presence in drifters from 1992 to the present, recent findings have shown that a significant number of drifters lost their drogues sooner than originally diagnosed.
3. The engineering aspects of the drifter drogues are being evaluated at Scripts Institution of Oceanography by Luca Centurioni and his group. They have redesigned the tether attachment to make it more resistant to stress, and have also enhanced the waterproofing seal. SIO is also evaluating the use of synthetic rope since the wire rope is most likely the weakest aspect of the design. SIO is building 20 drifters with the alternate material, and it is expected that this pilot array will be deployed soon. The Panel recommended to manufacturers to use the SIO drifter as a reference design (***recommendation; Manufacturers; ongoing***).
4. There is clear evidence that fitting lithium batteries to drifting buoys does give extended operating lifetime. For Argos drifters ~ ×1.75 and for Iridium drifters ~ ×1.77 (based on expired drifters excluding early failures <100 days and omitting the drifter that ran aground).
5. The excellent data availability and timeliness of Iridium buoys are confirmed.
6. Results are globally satisfactory for the SVP-BS (barometer+salinity) tested by Météo France.
7. Buoy lifetimes of buoys deployed by Environment Canada have ranged from a high of 1209 for a ICEX buoy from CMR, to failures on deployment or within only 30 days of deployment for some recent SVP-B deployments (MetOcean buoys). The network wide average lifetime (for all buoy types) over the past three years is 393 days. Lifetimes for SVP-B buoys from **MetOcean** (with mix of Iridium and ARGOS communications) have been in the range of 200-230 days, with a maximum of 553 days (based on sample of 10 buoys).
8. Initial results based on 3 month of data suggest that the observed wind speeds from sonic anemometers on 2 Minimet buoys manufactured by **Pacific Gyre** are likely useful for use in operational forecasting. However they may need to be corrected for height above the surface, especially at higher wind speeds.
9. Initial results from Marlin Yug study suggests that the quality of pressure reports from standard SVP-B drifter with 41-cm hull and alkaline batteries can remain reliable for 3 years at least under any weather conditions. The Panel noted that long-living drifters with 41-cm hulls and reliable AP measurements could be deployed in high latitudes, while the mini drifters with smaller hull diameter and shorter lifetime could be used in low latitudes.
10. Successful testing of new “micro” drifter (ice marker) with 20-cm float.

6.2.3 The Panel recalled its decision at the previous Session that the manufacturers should play a strong role in the Task Team, and had nominated Mr Andy Sybrandy (Pacific Gyre, USA) as co-

Chairperson of the Task Team (on a rotating basis). At the same time, while discussing again the issue, the Panel acknowledged that the Chair and Co-Chair of the Task Teams should not be in a situation of conflict of interest. The Panel, while warmly thanking Mr Sybrandy for his substantial contributions to the work of the Task Team during the last intersessional period decided that the co-Chair position should not be a manufacturer, and nominated *[to be decided]* as new Task Team co-Chairperson.

6.2.4 The Panel thanked Mr Crout and the members of the Task Team for their efforts. The Panel formally elected Mr Crout to Chair the Task Team during the next intersessional period. The full report of the Task Team is provided in Appendix A of DBCP-28 preparatory document No. 6.2 as well as in the CD-ROM accompanying the DBCP Session final report.

Appendices: 2

APPENDIX A

REPORT BY THE DBCP TASK TEAM ON INSTRUMENT BEST PRACTICES AND DRIFTER TECHNOLOGY DEVELOPMENT

(Report for 2012)

Global Drifter Program/ Data Assembly Center (AOML)

During the 2011-2012 intersessional period the GDP did not deploy any new clusters of drifters for inter-comparison and evaluation due to delays in acquisition and recalls of drifters from two manufacturers. Instead the GDP/DAC has been focusing on lifetimes of drifters across the entire global array since 2005, by manufacturer and buoy type (SVP vs SVPB).

As reported at last year's DBCP meeting, battery problems with Clearwater and recent Technocean drifters, and manufacturing problems with Technocean drifters, have greatly reduced their lifetimes. More recent problems were found in Pacific Gyre and Clearwater PMT-bearing drifters operating in PTT mode, where higher power consumption was inferred from abbreviated lifetimes (typically ~180 days). The DAC is also conducting a re-evaluation of drogue presence in drifters from 1992 to the present. Recent findings have shown that a significant number of drifters lost their drogues sooner than originally diagnosed. A new methodology based on anomalous downwind ageostrophic motion has been applied to the data to reanalyze drogue presence that, together with information from submergence or tether strain and transmission frequency variations, will lead to a more accurate determination of when drifters lost their drogues. More information on the drogue reanalysis can be found in a paper submitted to the *Journal of Atmospheric and Oceanic Technology* by Lumpkin et al (manuscript available at: **http://www.aoml.noaa.gov/phod/dac/drogue_reassess.pdf)**. A complete report will be presented during the DBCP-28 Technical Workshop and submitted as a separate document.

The engineering aspects of the drifter drogues are being evaluated at Scripts Institution of Oceanography by Luca Centurioni and his group. They have redesigned the tether attachment to make it more resistant to stress, and have also enhanced the waterproofing seal. SIO is also evaluating the use of synthetic rope since the wire rope is most likely the weakest aspect of the design. SIO is building 20 drifters with the alternate material, and it is expected that this pilot array will be deployed soon. It has been recommended to manufacturers to use the SIO drifter as a reference design.

UK Met Office Drifter Evaluation

The UK Met Office continues to provide drifting buoys (with barometers) in the South Atlantic and the Southern Ocean. All drifters purchased have been ***MetOcean*** units and from 2007 have all been Iridium drifters and a contribution to the Iridium Drifter Pilot Project. Many of the drifters were ordered with lithium batteries in order to evaluate the potential increase in lifetime of the units.

The longest lived Argos drifter (from 5 units deployed) with alkaline batteries operated for 915 days, whereas the 2 longest surviving Argos drifters with lithium batteries (from 4 units deployed) operated for over 1,400 days.

The longest lived Iridium drifter (from 10 units deployed) with alkaline batteries operated for 463 days, whereas the longest surviving Iridium drifter with lithium batteries has operated for 1,355 days (as at 16th July 2012). A further 3 (from 10 units deployed in 2009) are still operating after over 960 days. 5 of 7 units deployed in 2010 and 2011 are also currently operating (one early failure most likely having been due to damage by pack ice, the other having run aground on Kerguelen island after 11 months at sea). These 7 units were HRSST-1 drifters also contributing to the DBCP/GHRSST HRSST Pilot Project.

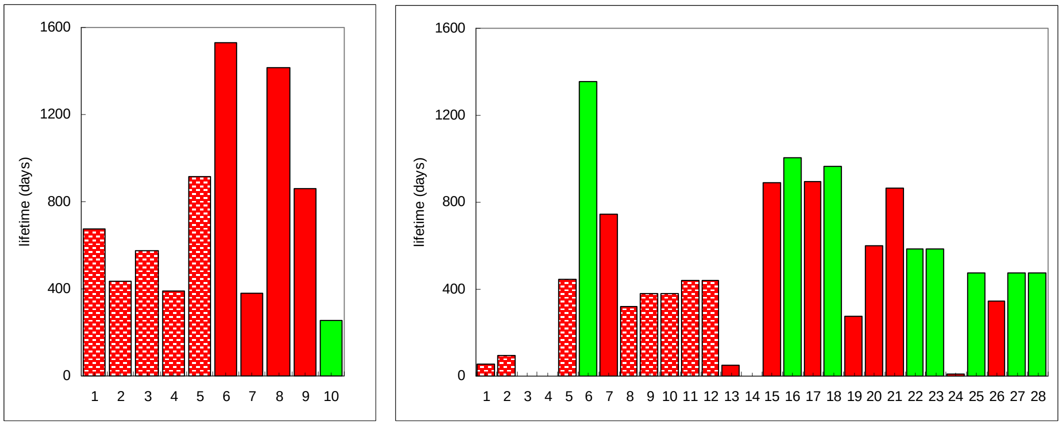

Figure 1: Lifetimes of Argos (left) and Iridium (right) drifters. Active drifters are shown in green, expired drifters in red, units with alkaline batteries are shown by hatched bars and with lithium batteries by solid bars.

Overall, there is clear evidence that fitting lithium batteries to drifting buoys does give extended operating lifetime. For Argos drifters ~ ×1.75 and for Iridium drifters ~ ×1.77 (based on expired drifters excluding early failures <100 days and omitting the drifter that ran aground).

We currently have 12 Iridium drifters with barometers available for deployment (9 with HRSST-2 upgrades) with a further 9 on order (including 6 HRSST-2 units). Contrary to expectation, it is not possible to dismount the sea temperature sensor for pre-deployment calibration checking.

<u>Meteo-France</u>

Iridium drifters

Since the last DBCP meeting, the Centre of Marine Meteorology of Meteo-France has been continuing to use and to evaluate the Iridium Short Burst Data (SBD) transmission on operational drifting buoys. Since the 1st of September 2011, more than one hundred Iridium SVP-B drifters built by Metocean for E-SURFMAR and twenty five ones for IBPIO (collaboration NOAA, DBCP, Meteo-France) were deployed. Ten buoys were also deployed in the Pacific Ocean (DBCP action) where the average transmission delays through Argos are too high. All the buoys have been fitted with a GPS. The excellent data availability and timeliness for these buoys are confirmed.

A lot of them launched in the E-SURFMAR area failed quickly after deployment or had a short lifetime. However, it appeared the problems were rather due to manufacture modifications than to the system itself. During 2011 Metocean worked a lot to bring the quality of SVP-B drifters back at the level it was previously. The problems are fixed by now and the buoys built by the end of 2011 seem to be reliable. Meteo-France will only use drifters with 41 cm hull fitted with the original drogue design in the future

Over the past 12 months, Meteo-France was also involved in various aspects of Iridium drifters through:

- the evaluation of SVP-BS (salinity drifters) (Metocean);
- the purchase of SVP-BTC (thermistor string) (Marlin Yug);
- the purchase of SVP-B to Pacific Gyre and Marlin-Yug
- the making of suitable dataformats for all these different buoys;
- the GTS data transmission for a majority of these buoys.

Improvements in SST measurements

Data users require a better accuracy for in situ SST measurements. According to the GHRSST group, drifting buoys are the best reference to validate (and possibly to calibrate) infrared and microwave satellite measurements. Iridium-PP raw data formats were adapted in order to allow a resolution of 0.01 K. Although FM-18 BUOY format does not allow to report SST with this resolution onto the GTS, FM-94 BUFR format does.

Metocean replaced former probe YSI 44032 they previously used (accuracy 0.1 K) with probe YSI 46000 (accuracy 0.05 K) on their buoys delivered to Meteo-France. The first deployments of HRSST-1 (High Resolution SST) buoys occured by fall 2010. However, in general, these analog probes are not calibrated after integration within the buoys. The next step consisted in building drifters, called HRSST-2, equipped with digital SST probes which may be pre-and post calibrated separately. The first HRSST-2 prototypes were deployed and seem promising. The accuracy of digital probes may reach 0.02 K (standard deviation of the measurement differences at night with a SeaBird sensor on 4 SVP-BS). More than 20 others buoys will be deployed in 2012-2013.

SVP-BS (salinity) and SVP-BTC (temperatures in depth)

In cooperation with LOCEAN, Meteo-France continued to use SVP-BS drifters from Metocean and Pacific Gyre. Seven Iridium (Metocean) and fourteen Argos (Pacific Gyre) SVP-BS were deployed over the past 12 months. All are fitted with SeaBird sensors. Results are globally satisfactory. Since the SMOS satellite was launched, *in situ* salinity data have been used to validate and calibrate its remote salinity measurements.

About ten SVP-BTC buoys built by Marlin-Yug, equipped with a 80-metre long thermistor chain were purchased (16 sea temperature probes and one hydrostatic pressure sensor at its end). In addition to the temperature values, the buoy reports the depth of each probe according to the pressure value and an algorithm simulating the string shape. Those drifters will be deployed at sea in fall 2012 in Mediterranean Sea for HyMeX experiment.

Environment Canada

1. Environment Canada (EC) continues to deploy SVP-B buoys in three target areas; the Northeast Pacific Ocean, the Northwest Atlantic, as well as the Arctic Basin (primarily north and west of the Canadian Arctic archipelago). Arctic deployments include air deployable ICEX buoys manufactured by **CMR**, CALIB (Compact Air Launched Ice Beacons) from **MetOcean**, as well as the evaluation of the new AXIB (Airborne Expendable Ice Buoy) built by **LBI Inc**.

   Buoy lifetimes have ranged from a high of 1209 for a ICEX buoy from CMR, to failures on deployment or within only 30 days of deployment for some recent SVP-B deployments (MetOcean buoys). The network wide average lifetime (for all buoy types) over the past three years is 393 days. Lifetimes for SVP-B buoys from **MetOcean** (with mix of Iridium and ARGOS communications) have been in the range of 200-230 days, with a maximum of 553 days (based on sample of 10 buoys). EC is instituting more rigorous performance measurement of the drifting buoy deployments, and will report on loss of specific sensors (i.e. barometer) as well as drogue failure for all future deployments.

2. When available, Environment Canada is procuring and deploying buoys with Iridium Short Burst Data (SBD) communications. The main drivers for this are significant reduction in costs (compared to buoys using ARGOS modems), as well as improved timeliness of the

data. EC has worked with vendors including CMR to integrate Iridium modems into the ICEX-Air buoy from **CMR**, and hopes to have LBI equip their AXIB buoy with Iridium communications in 2012. **MetOcean** also provides their CALIB (Compact Air Launch Ice Beacon) with an Iridium SBD modem. Buoys which are destined for deployments in the Arctic Basin will be equipped with lithium batteries, to improve lifetimes in the extreme cold conditions.

3. Environment Canada has produced 2 Minimet buoys manufactured by **Pacific Gyre** which are equipped with a sonic anemometer installed on the standard SVP-B buoy. The anemometer is installed on modified buoy hull. EC is interested in the application of this type of buoy for deployments in remote areas of the Arctic including on multi-year ice-pack or on land in coastal environments, as this may offer a low-cost option to acquire in-situ measurements of wind speed/direction as well as air pressure. To test the feasibility and performance of this type of application, 2 of the buoys were installed on land in Gimili, Manitoba, and collocated within the compound of an EC Reference Climate Station, which provided measurements of wind speed and direction at 10 and 2.5 m. Three months of data was analyzed, and the initial results suggest that the observed wind speeds are likely useful for use in operational forecasting, however may need to be corrected for height above the surface, especially at higher wind speeds.

   The second phase of this project will see one of the Minimet buoys deployed (again on land) in the high Arctic, collocated to a Marine automatic weather station on Gateshead Island, while the other Minimet will be deployed near Barrow Alaska, as part of a buoy intercomparison project planned by Dr. Ignatius Rigor at the University of Washington. The continued testing of the Minimet buoy will hopefully determine the feasibility of making measurements from sonic anemometers for Arctic deployments. EC is interested in engaging other buoy manufactures to consider design improvements, which could for example increase the height of the anemometer and temperature measurements to at least 2.5 m above the surface, while keeping costs below $5K/unit.

<u>Marine Hydrophysical Institute and Marlin-Yug Ltd</u>

The status of all the drifters in this report was fixed by July 25, 2012.

Tracking of Argos-2 drifters

Two SVP-B buoys with 64 alkaline D-cells and with continuous mode in operation continue their movements, visible via Argos-2 tracking capabilities. The buoys were deployed by BOM Australia and kept their tracking capabilities for a very long period of time after deployment in South Ocean. The drifters are visible via JCOMMOPC web

http://wo.jcommops.org/cgi-bin/WebObjects/JCOMMOPS.woa/1/wo/aLRIIProQYwON6XRyNVDsg/0.0.96.3.

ID67381/WMO56531 was deployed on May 11, 2006 and emitted for 2268 days (6.2 years). GTS distribution was stopped on 1183 day (3.2 years). ID67379/WMO56532 was deployed on December 12, 2006 and emitted for 2059 days (5.6 years). GTS distribution was stopped on 710 day (1.9 years). This information demonstrates the adequate power budget of Argos-2 drifters and should force efforts of manufacturers to develop sensors with longer lifetime.

Iridium PP

Three Iridium SVP-B drifters with 41-cm hulls and 92-cm drogues, equipped with 64 alkaline D-cells, were deployed by SAWS in South Atlantic in late 2009 and early 2010. All had perfect status

of AP and SST on July 25, 2012. Two SVP-B drifters had GPS receivers with hourly samples. The buoy ID75811/WMO17526 had 984 days (2.7 years) in operation and buoy ID75812/WMO16551 – 835 days (2.3 years) correspondently. The tandem Iridium/GPS provided reliable GPS fixes in this area with rough weather conditions. Only 2% of the hourly GPS fixes were lost during 2.6 years. Current level of battery voltage could provide for a 3-year theoretical lifetime.

Third SVP-B drifter without GPS ID75814/WMO17572 keeps also operation and the current level of battery voltage after 954 days (2.6 years) allows for a 3.5-year theoretical lifetime at least.

Argos-3 PP

Five Argos-3 SVP-B mini drifters with 35-cm hulls and 61-cm drogues were successfully deployed by NZ MetService in the Tasman Sea in August-October 2010. One buoy continues operation for 665 day (1.8 years) after deployment. Two buoys came ashore and were re-deployed in February 2012. Thus, tree buoys are now in operation.

Iridium SVP-BTC60/RTC/GPS temperature-profiling ice buoy

The temperature-profiling ice buoy for investigation of thermodynamic variability down to 60 m in depth below ice was developed on basis of “marine” temperature-profiling drifter. Two buoys were built for University of Washington to be deployed in the Arctic for evaluation in-situ.

Quality of AP measurements.

The results of this year study in conjunction with last year results allow to assert that standard SVP-B drifter with 41-cm hull and alkaline batteries can keep the reliable AP data for 3 years at least under any weather conditions. This result confirms with a few buoys for both data links (Argos-2 and Iridium). Of course, more statistics should be accepted for final conclusion, but currents results are optimistic enough.

SVP-B mini drifters with 35-cm hull have a smaller number of batteries and correspondently shorter lifetime. The estimation of this kind of drifter capabilities can be taken from 2010 intercomparison drifters. Three buoys of last prototype were successfully deployed in August 2010. The AP data were perfect during full lifetime. We guess that this variant of drifter can keep quality of AP data for 2 years at least. One buoy from 5-drifter cluster started operation on May 16, 2012 after near 1.5 year silence. It seems the magnet was detached because of corrosion process, which took place for connecting details. The buoy has fresh batteries and barometric port with 1.5 year in-situ. It would be interesting to see its further capabilities.

We support last year conclusion about adaptability of standard and mini drifters. The long-living drifters with 41-cm hulls and reliable AP measurements under any weather conditions should be used in South Ocean and may be in North high latitudes, while the mini drifters with smaller diameter of float and shorter lifetime could be used in low latitudes, where there is large probability to get a buoy lost because of beaching or vandalism, but there is good probability to support density of drifter net by means of ships of opportunity.

Lifetime of drogues to be attached

First of all about our understanding why the drogues are lost. There are two possible variants to get a drogue lost. The first event could take place within 3 months after deployment. For second variant the loss could be on some day during 300-450 days interval.

The first event could be a consequence of "weak place" creation on tether during deployment of drifter, when bad weather conditions. The "weak place" means that small loop could be formed at some point of tether during submergence of drogue. Because float can "jump" under wave influence, this loop can be shrunk with creation of fissure on tether. The rupture of tether in this place can be within 3 months.

We study a few buoys beached in the Black Sea and it became visible that more often the "weak place" can be closer to drogue (lower part of tether).

If deployment takes place without creation of the "weak place" on tether, the buoy could keep its drogue attached during longer time. Of course, the situation during strong storm could be unexpected and "weak place" can appear under storm influence. Nevertheless, we guess that probability of "weak place" under storm influence is smaller in contrast with situation during deployment.

To decrease a probability of first variant to get the drogue lost, we started using for two last years the spiral packaging of tether in the clips, attached to radials of upper ring. This packaging allows keeping a tension of tether during submergence of drogue after drop of buoy to water. This variant of packaging is used since 2010 and we see that more buoys kept drogues attached longer.

Since this year we started also application of swivels inserted into tether below float. We think that swivel should prevent the influence on tether if a float two-forked rotation takes place. And second positive thing here could be to prevent creation of "weak place" on tether.

Prototypes of drifters with 20-cm hull.
New development got the “micro” drifter (ice marker) with 20-cm float. The parachute system was developed to drop the buoys on ice. The system allows keeping of a buoy vertical orientation independently of parameters of surface: flat firm ice or soft snow. The test drops were carried out from aircraft as well as from helicopter at late 2011-early 2012. Both experiments were successful. Tens markers are used now in north seas for investigation of ice movement during spring time. More simple parachute system was developed to drop buoys to water to use the buoy for tracking of oil spill.

NIOT

Indian drifter buoy was designed by NIOT and deployed off Sri Lankan coast using Indian Satellite and has been providing data

APPENDIX B

TERMS OF REFERENCE OF THETASK TEAM ON INSTRUMENT BEST PRACTICES & DRIFTER TECHNOLOGY DEVELOPMENTS

(as adopted at DBCP-XXIV)

Note: The DBCP Evaluation Group is being merged into this Task Team.

The DBCP Task Team on Instrument Best Practices & Drifter Technology Developments shall:

Instrument Best Practices and Quality Management

1. When required by the DBCP, evaluate quality of buoy data produced by specific types of buoys, as well as functioning, efficiency;

2. Review existing practices for automatic real-time buoy data quality control, and delayed-mode buoy data quality control, and possibly suggest design changes for improvement (sensors, hardware, software, data formats) in liaison with the Task Team on technological developments;

3. Address instrument evaluation issues; suggest specific tests and / or evaluation deployments in different sea conditions to DBCP members in order to evaluate buoy quality as described in (1) above;

4. Share experience and results of evaluation with the DBCP and other interested parties;

5. Review and recommend Best Practices; work on specific technical issues in order to facilitate standardization and liaise with the other DBCP Task Teams as appropriate (e.g., DBCP recommended Argos message formats); and

6. Define specific criteria for evaluation purposes (e.g. ocean areas, definition of acceptable quality data, e.g., early failures, lifetimes, delays, accuracies, resolutions, etc.);

Drifter technology developments

7. Investigate developments in the fields of sensor technology, on-board processing, buoy hardware, hull design, energy generation and storage in order to better meet user requirements in terms of the range, reliability and quality of observed parameters and their cost-effectiveness;

8. Regularly review and document operational and upcoming satellite telemetry systems in terms of their ability to address user requirements such as bandwidth, timeliness, availability, geographical coverage, reliability, service quality, technical support, energy consumption and cost;, and make specific recommendations to the communications service providers on required / desired enhancements;

9. Review operational platform location systems, and whether they meet the user requirements;

10. Propose to the DBCP and its Executive Board any evaluation activities and pilot projects that it deems beneficial to data buoy operators;

11. Propose recommendations, both upon request and unsolicited, to the Argos Joint Tariff Agreement. Such recommendations shall be passed via the DBCP Executive Board or the DBCP as appropriate; and

12. Evaluate, test, and promote buoy designs that are resistant to vandalism;

General

13. Review all relevant JCOMM Publications to make sure they are kept up to date, comply with Quality Management terminology, and adhere to the WMO Quality Management Framework (QMF);

14. Provide the DBCP Executive Board and the DBCP, both upon request and unsolicited, with technical advice needed for addressing the issues above; and

15. Submit reports to the DBCP Executive Board and to the DBCP at its annual session that describe intersessional activities and propose a Workplan for the next intersessional period.

Membership:

The membership is open to all Panel members. The Chairperson, appointed by the Panel , has selected the following team members:

Dr Richard Crout, NDBC (TT Chairperson);

Mr Pierre Blouch, Météo-France
Mr Shaun Dolk, NOAA / AOML
Mr Paul Freitag, NOAA / PMEL
Mr Michel Guigue, CLS
Mr Chris Marshall, Environment Canada
Mr Sergey Motyzhev, Marlin Yug
Ms Mayra Pazos, NOAA / AOML
Dr M Ravichandran, INCOIS
Mr Jean Rolland, Météo-France
Mr R. Venkatesan, NIOT, India
Mr David Murphy, Sea-Bird Electronics, USA

Mr Andy Sybrandy, Pacific Gyre (TT Co-Chairperson);
Ms Emily Daniel, MetOcean
Ms Julie Fletcher, MSNZ
Mr Frank Grooters, KNMI
Mr Robert Jensen, USACE
Mr David Meldrum, SAMS
Dr Luca Centurioni, SIO
Mr Steve Piotrowicz, NOAA
Dr. Tim Richardson, Liquid Robotics
Mr Jon Turton, UK Met Office
Mr Bill Woodward, CLS America
Technical Co-ordinator, DBCP

The Co-chairperson is representing the manufacturers and is selected on a rotating basis.

APPENDIX C

TITLE