WORLD METEOROLOGICAL ORGANIZATION

DATA BUOY COOPERATION PANEL

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REPORT BY THE TASK TEAM ON MOORED BUOYS (TT-MB)

(Submitted by Jon Turton (UK), Chair, TT-MB)

SUMMARY AND PURPOSE OF DOCUMENT

This document contains the report by the chairperson of the DBCP Task Team on Moored Buoys.

ACTION PROPOSED

The Meeting is invited to note the information contained in this document when discussing how it organises its work and formulates its recommendations.

Appendices: **A.** Report by the Task Team on Moored Buoys

B. Terms of Reference of the DBCP Task Team on Moored Buoys

DISCUSSION

6.3.1 Mr Jon Turton (UK), Chairperson of the Task Team on Moored Buoys (TT-MB), reported on the Task Team activities during the last inter-sessional period. Over the last few years the metadata needing to be collected for moored buoy systems has been defined and an initial system for its submission to JCOMMOPS was set up in February, with documentation and submitted metadata available via ftp://ftp.jcommops.org/DBCP/metadata/. At time of writing moored buoy metadata have been submitted by Brazil, Canada, Chile, France, Germany, Greece, India, Italy, Japan, South Korea and US. Other moored buoy operators are requested to generate and provide their metadata to the DBCP-TC. Note there is an action from OCG-6 for DBCP to provide a summary of its strategy for development and completeness of metadata records for OCG-7 in April 2016.

6.3.2 The Task Team was instrumental in the development and validation of the BUFR template (3-15-008) for moored buoy data, which is now operational. Up till now most metocean moored buoys have been reporting their data onto the GTS in FM13 SHIP code and some of these data are being converted to BUFR template 3-08-009 (B/C10 – originally developed for ship data) and are being transmitted in both codes. At the same time the tropical moored buoys (TAO, PIRATA and RAMA networks) have reported their data in FM18 BUOY and the legacy un-validated (deprecated) template for data buoys. In time all moored buoy BUFR data issued to GTS should transition to using template 3-15-008, at present only US/PMEL and Ireland (Met Eireann) are known to be doing so.

6.3.3 It has not been possible during the last year to progress the validation of the new BUFR template (3-08-017) for data from fixed platforms (e.g. offshore rigs and light vessels) which was developed as neither the templates for moored buoys or ships (VOS) are well suited to fixed platforms. This should be progressed during the next inter-sessional period.

6.3.4 The cost of ship time for servicing is an issue for many moored buoy operators and autonomous surface vehicles (ASVs) are increasingly being seen as an alternative to operating moored buoys. Almost all ASVs presently use the AirMar all-in-one weather station. However, there are questions whether the ASVs are sufficiently robust, cost effective and able to deliver data of equivalent accuracy. The JCOMM Observations Coordination Group has recommended that DBCP coordinate (or at least suggest JAMSTEC coordinate with others) the evaluation of these and other candidate technologies, possibly taking advantage of TPOS and/or related activities. The Panel discussed whether this should fall to the TT-MB or whether to establish a new Pilot Project on Autonomous Surface Vehicles (PP-ASV) and agreed that a pilot project would be more appropriate.

6.3.5 In parallel, at DBCP-29, it was recognized that DBCP should take the lead, working with the JCOMM TT-TDC, on developing suitable BUFR templates for the exchange of ASV data on GTS, and this will need to be progressed during the coming year.

6.3.6 During the year a number of technical developments to the various moored buoy systems and networks have been made, including:

> Brazil: The Brazil National Buoy Program comprises 10 moored meteoceanographic bouys operating along the coast; with 7 moored buoys (Axys 3M) currently in operation. It is planned for the deployment of one more moored buoy in 2015.
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> India. Under the Ocean Observation Network program of the Ministry of Earth Sciences, National Institute of Ocean Technology (NIOT) has established the moored buoy network in the Indian Seas. Currently 18 moored buoys are working in Northern Indian Ocean region. Out of which 12 are having meteorological and oceanographic sensors up to 500m depth transmitting data in real time though INMARSAT with a data return of more than 93%. India has developed moored buoy called “Prakruti” to transmit 106 parameters in real time. Under Indo US collaboration a new buoy called “Monsoon Buoy” by WHOI was installed in the Bay of Bengal.
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> UK: Further deployment of new design moored buoys with spectral wave capability to replace legacy designs, with sub-hourly data reported from one new system. Evaluation of moored

buoy wave measurements is continuing as a contribution to the PP-WET. Initial evaluations of several ASV have been carried out as part of the MASSMO (Marine Autonomous Systems in Support of Marine Observation) project.

US: Testing of PMEL's T-Flex mooring system, intended to replace the legacy ATLAS moorings in RAMA and PIRATA, has been completed.The first replacement of an ATLAS system occurred in August 2015 at a RAMA site. Additional replacements of ATLAS with T-Flex systems in RAMA and PIRATA are planned for later in 2015 and in 2016.

USACE: Three dual sensor payloads onboard NOAA/NDBC 3D buoys (two in the Pacific, one in the Atlantic) continue to collect wave data for the intra-measurement evaluations. FLOSSIE (Field Laboratory for Ocean Sea State Investigation and Experimentation) a 6N (NOMAD) buoy was deployed 07/2015 in Monterey Canyon as part of the Buoy Farm inter-measurement evaluation. This is a collaborative effort between the USACE, NOAA/NDBC, Environment Canada and the AXYS™. Multiple sensor/payload packages onboard FLOSSIE will provide valuable data used in the intra-measurement evaluation. This deployment complements the 3D NOAA/NDBC dual sensor system, a Datawell™ directional Waverider buoy, and a TRIAXYS buoy to be deployed in the future provided by AXYS™. Additional information regarding the dual sensor buoys and FLOSSIE are documented as part of the DBCP-ETWCH Joint Pilot Project on Wave Measurement Evaluation and Testing.

6.3.7 The meeting agreed on the following:

1. Recommendation: that all centres issuing moored buoy data to the WMO GTS transition to BUFR template 3-15-008 as soon as possible, with dual BUFR/TAC dissemination to summer 2016 to allow operational centres to be ready for the change.

2. Recommendation: to progress work on validating the BUFR template for offshore platforms (3-15-017) and to develop a suitable template for ASVs.

3. The DBCP agreed to help coordinate work being carried out by various panel members on the evaluation of ASVs and to use its annual Scientific and Technical Workshop as a forum for presenting latest results.

6.3.8 The Panel thanked Mr Turton and the members of the Task Team for the report. The Panel elected <tbd> to Chair the Task Team during the next inter-sessional period. The full report of the Task Team is provided in Appendix A of DBCP-31 preparatory document No. 6.3, and will be included in the DBCP Annual Report for 2015.

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APPENDIX A

REPORT BY THE TASK TEAM ON MOORED BUOYS (TT-MB)

1. Technical developments

Information provided below is supplementary to that given in the National Reports.

1.1 Tropical Moored Buoy Array

1.1.1 Testing of PMEL's T-Flex mooring system, intended to replace the legacy ATLAS moorings in RAMA and PIRATA, has been completed. The first replacement of an ATLAS system occurred in August 2015 at a RAMA site. Additional replacements of ATLAS with T-Flex systems in RAMA and PIRATA are planned for later in 2015 and in 2016. Hourly T-Flex data are placed on the GTS by PMEL using BUFR format with Bulletin Header IOBX08 KPML. WMO numbers for T-Flex moorings will take the 7-digit representation of the 5-digit code for the previous ATLAS system at the same site. For example, the WMO number for the first T-Flex mooring implemented (4°S 81°E) will be 2300010 (vs 23010 for the previous ATLAS moorings at that site).

1.1.2 PMEL and China's First Institute of Oceanography (FIO) conducted a land-based, side-by-side test of meteorological sensors from ATLAS, T-Flex and FIO's BaiLong moorings in 2014 to ensure compatibility of measurements within RAMA. A NOAA Technical Memorandum on the test will be published in 2015.

1.1.3 Recent enhancements to tropical mooring observations include: Dalhousie University's Ocean Tracking Network (OTN) program has deployed acoustic telemetry receivers on all but one PIRATA surface moorings and 4 RAMA moorings, adding additional biological monitoring capabilities to the array by tracking marine animals. Additional deployments on RAMA and TAO moorings are planned. Oregon State University continues to deploy microstructure measuring instruments (known as ChiPods) on tropical moorings in TAO, PIRATA and RAMA. At present a total of 33 instruments are deployed on 9 moorings

1.2 PMEL OCS Stations

1.2.1 In addition to the tropical arrays, PMEL Ocean Climate Stations (OCS) continues to contribute to the OceanSITES network of time series reference sites with two stations: the Kuroshio Extension Observatory (KEO), located south of the Kuroshio Extension at 144.6°E, 32.3°N, and Station Papa, located in the eastern subarctic Pacific at 144.9°W, 50.1°N. Both moorings carry a suite of sensors to monitor air-sea exchanges of carbon dioxide, heat, and freshwater; wind; upper ocean temperature, salinity, and near-surface currents; ocean acidification; important aspects of the carbon cycle in the surface water; and bottom water temperature and salinity. Moorings deployed in 2014 and 2015 were instrumented with 2 PMEL Flex (similar to T-Flex) systems which provide duplication in most meteorological observations. Previous moorings included both Flex (which telemeters data via Iridium) and legacy ATLAS systems (which use Argos). The KEO mooring is maintained in partnership with JAMSTEC; Station Papa is maintained in partnership with the Canadian DFO Line P Program.

1.2.2 Most of the KEO and Station Papa data are available in near real-time through the project website: http://www.pmel.noaa.gov/OCS/, and through the GTS. Data telemetered via Iridium are coded into BFUR at PMEL and submitted to the GTS via an NWS gateway using Bulletin Headers IOBB18 KPML (KEO) and IOBC18 KPML (Papa) Their WMO numbers contain the digits "84" identifying them as reference stations (KEO's is 2800401 and Papa's is 4800400). It is recommended that these GTS reference data should be withheld from all data assimilations so that they can be used as independent validation of the numerical products.

1.3 USACE moored buoy network

1.3.1 The US Army Corps of Engineers (USACE) continues to operate ~60 buoys along the US coast, the Hawaiian Islands, Puerto Rico, Guam, Marshall, and Saipan, collaborated with other US Federal (US Navy, NOAA/IOOS), State (California, Virginia) agencies, Local, and industry partners. Data are disseminated via the Coastal Data Information Program (CDIP). All wave measurements are obtained from Datawell Directional Waverider buoys. IRIDIUM communications are used in ~100% of the sites. Real-time data return on the deployed buoys is ~99%. New protocols in the IRIDIUM communications allow for automatic data filling for incomplete records. Failures of the system generally are a result from vessel collisions five in total (recovered and returned to servic e). Two buoys were lost. In 2015 there was an increase of three sites, two in the Southern California Bight, and one in the Gulf of Mexico offshore Tampa, FL.

1.4 Met Office moored buoy network

1.4.1 The Met Office moored buoy network presently includes seven operational deep ocean buoys from the north of Scotland (K7) to the west of the British Isles (K5, K4, K2, K1) down to Biscay (Brittany, Gascogne), where the two buoys in Biscay are operated in collaboration with Meteo-France. These buoys are funded through the Public Weather Service Programme, apart from K7 which is mainly funded by the offshore oil and gas industry. A further two buoys are operated off the coast of South Wales for the Milford Haven Port Authority (Turbot Bank) and QinetiQ (Aberporth). Additional moored buoys are operated in collaboration with the National Oceanography Centre (NOCS) at the OceanSITES Porcupine Abyssal Plain (PAP) station and Celtic Sea (deployed in support of the CANDYFLOSS research programme), and with Plymouth Marine Laboratory (PML) at E1 in the Western Channel. A Met Office AMOS (Autonomous Marine Observing System (as deployed on ships) is also installed on the PML L4 buoy in the Western Channel. All the buoys have dual meteorological systems, other than the buoys at PAP and E1 which only have a single met system as the other side is used for the oceanographic system. The PAP buoy has an instrument frame suspended 30m below the buoy and the E1 buoy has a winching system designed to lower/raise PML's optical sensors out of the water for cleaning. At present the met and wave data from the buoys are still reported to GTS in WMO FM-13 SHIP format and (as a temporary solution) are converted to BUFR 3-08-009.

1.4.2 The network buoys, which were designed during the early 1990s, are increasingly difficult to maintain as some of their components are ageing/obsolete (e.g. CR10x/PC42 electronics and Meteosat DCPs) and a replacement programme is underway, where K1, K7, Aberporth and E1 are now based on new design systems using the Axys Watchman 500 and Triaxys spectral wave sensor on Hydrosphere/Mobilis hulls. However, water ingress into the Triaxys enclosures leading to corrosion has been a problem and we have also experienced similar problems with the Watchman units. It is likely that future systems will utilize the CR1000 data logger (as used on AMOS) in place of the Watchman's, although this will require further software development to permit cross-linking of the dual sensor and Iridium transmission systems.

1.4.3 Wave measurements on the old design buoys are made using a Datawell heave sensor, although on K5, Brittany, Gascogne and Celtic Sea buoys Triaxys spectral wave systems are also fitted (enabling comparison of measurements). On K1, K7, E1, Aberporth and PAP only a Triaxys is fitted. The moored buoy at Aberporth is the first to deliver sub-hourly measurements and in addition to the Triaxys has a Datawell MOSE-G sensor on board logging data. A Datawell Waverider is also being operated nearby in order to provide comparison data for the wave measurements in support of the PP-WET initiative.

1.4.4 The MASSMO (Marine Autonomous Systems in Support of Marine Observation) project is being led by the National Oceanography Centre and aims to undertake field trials in order to test new marine autonomous platforms and sensors purchased as part of recent NERC MARS capital funding. This includes ASVs purchased from Liquid Robotics, ASV and MOST. Phase 1 of MASSMO was carried out in autumn 2014 and allowed some limited comparisons of the capability of several of the vehicles to make metocean measurements. Various results were presented at the MASSMO Workshop in January 2014 (see http://noc.ac.uk/conference/mars). Further evaluations are proceeding under MASSMO2 and also on comparing met measurements from the AMOS on the L4 buoy against an Airmar weather station also on the buoy.

1.5 Indian Moored Buoy Network

1.5.1 Under the Ocean Observation Network program of the Ministry of Earth Sciences, National Institute of Ocean Technology (NIOT) has established the moored buoy network in the Indian Seas. Considering the importance of continuous measurements of data of high reliability and quality, which is of scientific relevance, optimal numbers of buoys are maintained at strategic locations in the Bay of Bengal and Arabian Sea. Currently 18 moored buoys are working in Northern Indian Ocean region. Out of which 12 of them are having meteorological and oceanographic sensors up to 500m depth transmitting data in real time though INMARSAT having data return of more than 93%. India has developed moored buoy called “Prakruti” to transmit 106 parameters in real time. The Coastal buoys are equipped with Indigenous Buoy Data Acquisition System to transmit data through INSAT, INMARSAT and GPRS. For Indian satellite data validation a data buoy and an optical buoy are deployed in tandem in Arabian sea. Data seta are made available through GTS Under the Indo-US project, Woods Hole Oceanographic Institution, has deployed a well-instrumented air-sea interaction mooring at 18°N/89°E to collect measurements of the air-sea exchange of heat, momentum, and freshwater and the coincident evolution of the upper ocean. INCOIS has deployed one subsurface mooring in the southern Bay of Bengal. NIO Goa is maintaining 4 ADCP subsurface moorings in coastal waters. Wave rider buoys are deployed in 10 locations

1.5.2 The IndARC-I moored observatory was deployed and recovered from the Norwegian Polar Institute’s research vessel R.V. Lance at 78°57´ N / 12°01´E, about 1100 km away from the North Pole at a water depth of 192 m. It has an array of ten state-of-the-art oceanographic sensors strategically positioned at discrete depths in the water column. Seawater temperature and salinity data were collected from discrete depths at 22, 30, 55, 80, 105 and 140m from July 2014 to July 2015. The moored observatory was successfully retrieved on 15th July 2015. The data from all the sensors were downloaded successfully. Subsequently, the IndARC II mooring with additional sensors to measure PAR, nitrate, and ambient noise was deployed on 19th July 2015.

1.5.3 Data return is dependent on long term performance of sensors and accessories like connectors battery etc. As ship time availability and cost involved is a major difficulty in these projects there is an urgent need to interact among buoy operator to share experience and expertise on sensors and lessons learned

APPENDIX B

TERMS OF REFERENCE OF THE DBCP TASK TEAM ON MOORED BUOYS (TT-MB)

(as adopted at DBCP-24)

The DBCP Task Team on Moored Buoys shall:

1. Review and document operational moored buoy systems and their underlying requirements;

2. Liaise with the different communities deploying moorings, including TIP, OceanSITES, seabed observatories, as well as national moored buoy programmes (coastal and global), and promote the development of multi-disciplinary mooring systems;

3. Liaise with the GOOS Scientific Steering Committee (GSSC) and its technical sub-panel for Integrated Coastal Observations (PICO) to facilitate synergy between advances in GOOS implementation and the development of operational capabilities, in particular, for sustained coastal observations, analysis and related services by using mooring systems;

4. Liaise with the JCOMM Expert Team on Wind Waves and Storm Surges (ETWS) regarding the need for in situ wave observations;

5. Compile information on opportunities for the deployment and / or servicing of moored buoys;

6. Monitor technological developments for moored data buoys and liaise with the Task Team on Technological Developments on satellite data telecommunication aspects;

7. Review all relevant WMO and IOC Publications on Instrument Best Practices (e.g., JCOMM, CIMO) to make sure they are kept up to date, address WIGOS issues, and comply with Quality Management terminology;

8. Provide the DBCP Executive Board or the DBCP with technical advice needed for developing moored buoy programmes, including the issues above; and

9. Report to the DBCP Executive Board and the DBCP at its biennial Sessions, with periodically updated Workplans supporting implementation.

Membership:

The membership is open to all Panel members. The Chairperson[1] and Vice-Chair are appointed by the Panel:

Mr Jon Turton, UK Met Office (TT Chairperson); (TT Vice-Chairperson – to be appointed)

Mr Gilbert Emvizat, Meteo-France
Ms Champiks Gallage, DBCP-TC
Dr Robert Jensen, USACE
Mr Shannon McArthur, NOAA/NDBC
Mr Chun Lin Ning, FIO China
Cdr Felipe Santos, NHC Brazil
Dr Val Swail, Env Canada
Mr Ariel Troisi, SHN
Mr Paul Freitag, NOAA / PMEL
Mr Michel Guigue, CLS
Mr Chris Marshall, Env Canada
Mr Chris Meinig, NOAA / PMEL
Mr Tim Richardson, Liquid Robotics
Mr Johan Stander, SAWS
Mr Andy Sybrandy, Pacific Gyre
Dr Hedinn Valdimarsson, MRI Iceland

1 The Chair and Co-Chair of the Task Team should not be in a situation of conflict of interest.

Dr R. Venkatesan, NIOT, India
Dr Robert Weller, WHOI
Mr Scott Woodruff, NOAA