**Report by the DBCP TIP Action Group to the**

**Thirty-SIXth session of the DBCP (DBCP-36)**

*(Virtual session, 05-08 Oct 2020)*

**1) Summary**

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| **Name of Action Group** | **Tropical Moored Buoy Implementation Panel (TIP)** |
| **Date of report** | 17 September 2020 |
| **Overview and main requirements addressed** | The Tropical Moored Buoy Implementation Panel (TIP) coordinates the design and implementation of the following components:* The Tropical Atmosphere Ocean / Triangle Trans-Ocean Buoy Network (TAO / TRITON), a central component of the ENSO Observing System, deployed specifically for research and forecasting of El Niño and La Niña;
* The Prediction and Research Moored Array in the Tropical Atlantic (PIRATA)
* The Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA)
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| **Area of interest** | The tropical ocean regions as part of an integrated approach to observing the climate system to address the research needs of CLIVAR and the operational strategies of GOOS and GCOS. Pacific Ocean: 8°N to 8°S; Atlantic Ocean: 21°N to 19°S; Indian Ocean: 15°N to 12°S. |
| **Type of platform and variables measured** | Tropical moored buoys with surface meteorological and sub-surface oceanographic sensors measuring surface wind, air temperature, relative humidity, SST and SSS on all surface moorings. Air pressure, precipitation, shortwave radiation, longwave radiation on some surface moorings. Sub-surface temperature profiles down to 500m on all surface moorings. Salinity profiles as deep as 140m on some surface moorings. Current velocity on some moorings. Biogeochemical measurements, including CO2 and O2, are included on select moorings. Most moorings also have passive acoustic monitoring receivers for tracking marine animals and some have specialized instruments to measure turbulence dissipation.Tropical subsurface ADCP moorings measure velocity profiles in the upper 300 meters. |
| **Targeted horizontal resolution** | **Tropical Pacific Ocean:** 61 moorings in TAO/TRITONTAO: 59 moorings (55 surface and 4 subsurface ADCPs)TRITON: 2 moored surface buoys (these two remaining TRITON surface moorings are scheduled to be retired following the next recovery cruise); one (1) subsurface ADCP mooring at 0°-,156°E (not formally part of TRITON); and one additional surface mooring at 13°N,137°E (which is not formally part of TRITON, but aligned with the northern region of 137°E line of TAO/TRITON).**Tropical Atlantic Ocean:** 19 moorings in PIRATA (18 surface and 1 subsurface ADCP)**Tropical Indian Ocean:**  33 moorings in RAMA (28 surface and 5 subsurface ADCPs) |
| **Chairperson/Managers** | Dr. Mike McPhaden, PMEL, USA, ChairmanDr. Kentaro Ando, JAMSTEC, Japan, Vice-Chairman |
| **Coordinator** | Mr. Kenneth Connell, PMEL, USA |
| **Participants** | **TAO/TRITON:** NOAA National Data Buoy Center (NDBC), NOAA Pacific Marine Environmental Laboratory (PMEL), Japan Agency for Marine-Earth Science and Technology (JAMSTEC) **PIRATA:** NOAA Pacific Marine Environmental Laboratory (PMEL), NOAA Atlantic Marine Oceanographic Laboratory (AOML), L'Institut de recherche pour le développement (IRD), Meteo-France, GEOMAR, Instituto Nacional de Pesquisas Espaciais (INPE), Diretoria de Hidrografia e Navegacao (DHN)**RAMA:** NOAA PMEL, Indian National Institute of Ocean Technology (NIOT), Indian National Center for Ocean Information Services (INCOIS), Indonesian Meteorological, Climate, and Geophysical Agency (BMKG), the Indonesian Agency for the Assessment and Application of Technology (BPPT), JAMSTEC, the Chinese First Institute of Oceanography (FIO), and Bay of Bengal Large Marine Ecosystem (BOBLME) program. |
| **Data centre(s)** | PMEL, NDBC, Coriolis (EU), JAMSTEC, NCEI, INCOIS |
| **Website** | <https://www.pmel.noaa.gov/gtmba/><https://tao.ndbc.noaa.gov/><http://www.jamstec.go.jp/jamstec/TRITON/real_time/><http://www.brest.ird.fr/pirata/data.php>  |
| **Meetings***(meetings held in 2019/2020; and planned in 2020/2021)* | * Oceans 2019, Seattle, WA, USA, 27-31 October 2019
* Ocean Sciences Meeting 2020, San Diego, CA, USA, 16-21 February 2020
* US CLIVAR Surface Currents in the Coupled Ocean-Atmosphere System Workshop, February 2020, San Diego, CA
* OceanSITES meeting, virtual session, Sep 2020
* Ocean Best Practices meeting, virtual session, Sep 2020
* DBCP, virtual session, Oct 2020
* IIOE2 meeting , GOA, India, TBD
* PIRATA annual meeting, TBD
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| **Current status summary** *(As of September 2020)* | ***Pacific Ocean TAO/TRITON:**** 47 of 55 TAO moorings reporting data
* 4 of 4 TAO ADCP moorings currently deployed
* Two impending cruises: August 2020, TA-20-03-BLFN (165E/180W meridians) and September 2020, TA-20-04-BLFN (170W meridian)
* 2 of 2 TRITON moorings (0°-,156°E and 8°N, 137°E) reporting data (but both appear to have abnormal winds from mid-April 2020 to present).
* 1 of 1 TRITON mooring at 13°N, 137°E reporting data (not formally established as part of TRITON array).
* 1 of 1 ADCP mooring currently deployed at 0°-,156°E (not formally established as part of TRITON array)

***Atlantic Ocean PIRATA:**** 15 of 18 PIRATA moorings reporting data
* 1 of 1 PIRATA ADCP mooring currently deployed

***Indian Ocean RAMA:**** Currently 30 of 33 moorings (26 of 28 surface moorings) implemented: 3 moorings have not been implemented yet; 3 additional moorings currently suspended
* 19 of 28 RAMA surface moorings reporting data
* 4 of 4 RAMA ADCP moorings currently deployed
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| **Challenges/Opportunities/Risks** *(intersessional period- highlighting the impact of COVID19 and mitigation plans)* | An existing challenge for NOAA/NDBC is managing a pending technology obsolescence of components within the TAO buoy payload. To mitigate the impact of this risk NDBC is initiating a project to refresh the TAO buoy technology.Ship time continues to be a challenge, with plans for deferring service of two meridional lines in fiscal year 2021.The COVID-19 global pandemic has created significant challenges for maintaining the tropical moored buoy arrays. In 2020 there were five cancelled or postponed cruises in RAMA and two cancelled or postponed cruises in PIRATA. NOAA/PMEL is working with NOAA and partner institutions to try to schedule cruises for 2021, but this continues to be a major hurdle to overcome. Delays in cruise scheduling present a significant risk to the tropical moored buoy arrays. Several moored buoys have already gone adrift and several more moorings are shutting down due to long deployment periods well in excess of the design life.Because of the situation of the COVID-19, it is difficult to schedule and conduct a long-distance JAMSTEC cruise. Negotiation with Indonesian institutes to conduct cooperative (Japan/Indonesia) cruise have also been postponed for the time being due to the pandemic.The COVID-19 pandemic will affect the joint China/Indonesia cruise in 2021. Negotiation with Indonesian institutes to conduct cooperative (China/Indonesia) cruise have also been postponed for the time being due to the pandemic. These cruise delays place additional risk on the Bailong surface buoy and subsurface ADCP mooring maintained by FIO.The Tropical Pacific Observing System 2020 project (TPOS 2020) continues to make progress on redesign and refining the TPOS to observe ENSO and advance science, to advance efficient and effective observational solutions, and to advance understanding of tropical Pacific physical and biogeochemical/ecosystem variability and predictability. Two AGU sessions on Tropical Pacific research and observations related to TPOS 2020 will be held during the American Geophysical Union Fall Meeting.  |
| **Summary of plans for 2021** | **TAO/TRITON:** Maintain 59 TAO mooring array. recover 2 TRITON mooring array (these sites will be retired). Maintain 1 additional TRITON mooring and 1 additional ADCP mooring that are not formally TAO/TRITON moorings.**PIRATA:** Maintain 19 mooring array.**RAMA:** Maintain 27 moorings in the array if cruise scheduling is possible during ongoing pandemic. 3 moorings have been suspended due to excessive vandalism or ship-time limitations. |

**2 Deployment plans for 2021**

Details on deployment plans, and opportunities for next year are presented by each ocean basin below:

**Pacific Ocean:**

* March 2021 (125W/140W) , 14 moorings and 1 ADCP mooring
* June 2021 (95W/110W) , 14 moorings and 1 ADCP mooring
* Fall 2021 (155W) , 7 moorings
* Fall 2021 (180W) , 7 moorings
* Late 2021 (One cruise for mooring operations in the western Pacific will be conducted before the end of 2021 to service 3 surface moorings and 1 ADCP mooring. The cruise plan has not been confirmed yet, because of the ongoing COVID-19 pandemic.

**Atlantic Ocean:**

* Oct/Nov 2020 (14°S - 15°N, 30°W -38°W), 7 surface moorings (R/V Antares)
* Feb/Mar 2021 (8°S - 19°S, 30°W - 34°W), 6 surface moorings and 1 ADCP mooring (R/V Thalassa)
* TBD 2021 (0°N - 21°N, 23°W -38°W), 4 surface moorings (NOAA Ship TBD)

**Indian Ocean:**

* TBD 2021 (90°E), 4 surface moorings (R/V Baruna Jaya)
* TBD 2021 (67°E), 6 surface moorings and 4 ADCP moorings (R/V Sagar Nidhi)
* TBD 2021 (80.5°E), 8 surface moorings and 1 ADCP mooring (R/V Sagar Nidhi)
* TBD 2021 (55°E), 2 surface moorings (M/V Tethys Supporter)
* TBD 2021 (90°E to 95°E), 2 surface moorings and 1 ADCP mooring (R/V Baruna Jaya)
* TBD 2021 (8°S, 100°E and 8.5°S, 107°E), 1 surface buoy and 1 ADCP mooring (R/V Baruna Jaya)

**3 Data management**

3.1 Distribution of the data

Most tropical surface mooring data are telemetered in real time and are placed on the GTS for use by operational weather, climate and ocean forecasting centres around the world. High-resolution TAO Refresh data are telemetered via Iridium and placed on the GTS by NDBC. TRITON data and data from ATLAS moorings (about half of the systems in PIRATA and RAMA) are telemetered via the Argos system and are placed on the GTS by the French Space Agency (CLS). Data from recently deployed T-Flex moorings in PIRATA and RAMA are telemetered via Iridium and placed on the GTS by PMEL. Real-time data, delayed-mode data (e.g., data of higher temporal resolution than are available in real time) and data from subsurface moorings are available via several web based distribution sites, including the PMEL GTMBA website and GDACs at NDBC and Coriolis:

* PMEL (<https://www.pmel.noaa.gov/gtmba/data-access/disdel>),
* NDBC (<https://tao.ndbc.noaa.gov/tao/data_download/search_map.shtml>),

 (<https://dods.ndbc.noaa.gov/thredds/catalog/data/oceansites/DATA/catalog.html>), and

 (ftp://data.ndbc.noaa.gov/data/)

* Coriolis (<http://www.coriolis.eu.org/Data-Products/Data-Delivery/Data-selection>)

 (ftp://ftp.ifremer.fr/ifremer/oceansites)

* JAMSTEC ([www.jamstec.go.jp/jamstec/TRITON/real\_time/delivery/](http://www.jamstec.go.jp/jamstec/TRITON/real_time/delivery/))

 ([www.jamstec.go.jp/iorgc/iomics/datadisplay/buoysummary.php?LANG=0](http://www.jamstec.go.jp/iorgc/iomics/datadisplay/buoysummary.php?LANG=0))

3.1.1 Data policy

Data are freely available on the web and distributed via the GTS in real-time. The protocol for TAO-Refresh data delivery is based on an Open Source Project for a Network Data Access Protocol (OPeNDAP).

3.1.2 Real-time data exchange

TAO Refresh systems, designed to make observations comparable to legacy ATLAS systems, transmit 10-min data via Iridium, with hourly observations placed on the GTS by NDBC. ATLAS moorings place daily mean meteorological and oceanographic observations and some (about 10 per day on average) hourly meteorological observations on the GTS using Argos2 PTTs. TRITON and mini-TRITON (m-TRITON) buoys submit hourly mean meteorological and oceanographic data to the GTS: TRITON via Argos2 PTTs and m-TRITON via Argos3 PMTs. Hourly T-Flex data transmitted via Iridium are placed on the GTS by PMEL. Compared to the volume of ATLAS data received at PMEL, more than 90% is typically reported on the GTS by CLS. Most operational centers receive nearly all ATLAS data placed on the GTS, with the exception of the European Centre for Medium Range Weather Forecasts (ECMWF), which typically reports volumes of about 75%, presumably due to stricter latency criteria.

NDBC submits TAO Refresh data onto the GTS under the SSVX08 KWNB header in World Meteorological Organization (WMO) FM18 – BUOY alphanumeric format and also in BUFR format under header ISSF/G08. The WMO numbers for the TAO Refresh buoys are those used for the previous ATLAS moorings at the same sites. PMEL submits T-Flex data onto the GTS in BUFR format with Bulletin Header IOBX08 KPML. WMO numbers for T-Flex moorings take the 7-digit analogue 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 in RAMA) is 2300010 (vs 23010 for the previous ATLAS moorings at that site).

3.1.3 Delayed mode data exchange

Delayed mode data (i.e., data retrieved after mooring recovery) are available at the web sites listed in 3.1 above. System metadata are available at the web sites listed in 3.2 and 4 below.

The TAO web sites (https://tao.ndbc.noaa.gov/ and <https://www.pmel.noaa.gov/gtmba/pmel-theme/pacific-ocean-tao>), PIRATA web site (<https://www.pmel.noaa.gov/gtmba/pirata>), and RAMA web site (<https://www.pmel.noaa.gov/gtmba/rama>) provide additional information including scientific background, technical information, present status of the arrays, bibliographies of refereed publications, history of cruises, and additional information.

TAO delayed mode data are archived by NDBC following the definitions and principles of the Open Archival Information System (OAIS) Model (ISO 14721:2003); these data are available at NOAA National Center for Environmental Information:

<https://data.noaa.gov/dataset/physical-and-meteorological-data-from-the-tropical-atmosphere-ocean-tao-array-in-the-tropical-p0a3d0>

3.2 Data quality

Data quality control procedures are described at <https://www.pmel.noaa.gov/gtmba/data-quality-control> for T-Flex and ATLAS moorings, at <http://tao.ndbc.noaa.gov/proj_overview/qc_ndbc.shtml> for TAO refresh moorings and at <http://www.jamstec.go.jp/jamstec/TRITON/real_time/overview/po-d5> for TRITON moorings.

**4) Instrument practices**

Sensor specifications and calibration procedures are described on a number of web sites:

* <https://www.pmel.noaa.gov/tao/proj_over/sensors.shtml> (ATLAS and T-Flex)
* <https://tao.ndbc.noaa.gov/proj_overview/sampling_ndbc.shtml> (TAO Refresh)
* <http://www.jamstec.go.jp/jamstec/TRITON/real_time/overview/> (TRITON)
* <http://www.jamstec.go.jp/iorgc/iomics/projectoverview/1_b3_eng.html> (m-TRITON)

Real-time (daily averaged) and delayed mode (10-minute) data from NDBC’s TAO Refresh moorings and PMEL’s T-Flex moorings were independently compared during testing alongside ATLAS moorings for several years. TAO Refresh moorings have now replaced all ATLAS Legacy moorings in TAO. Side-by-side T-Flex/ATLAS comparison deployments were also conducted for several years. T-Flex moorings have now replaced ATLAS moorings at 9 RAMA and 10 PIRATA sites. No new mooring transitions from ATLAS to T-Flex are planned for the coming year.

**5) Details of Challenges/Opportunities/Risks**

Damage to buoys and theft of instrumentation continues to be a problem, especially at sites in areas of intense fishing activity. Refer to the vandalism report for further details on specific vandalism impacts to the tropical moored buoy arrays.

The COVID-19 global pandemic has created significant challenges for maintaining the tropical moored buoy arrays. The TAO array has experienced minor impacts as a result of the COVID-19 pandemic because pre-established contracted charter cruises have continued during the pandemic. These small impacts are related to business closures and longer than normal lead times for sensor refurbishments. However, the PIRATA and RAMA arrays have experienced some significant impacts related to cruise cancellations that have led to extended deployment periods and increased risk of loss of moored buoys and data. Ship time continues to be a challenge in TAO array as well, with plans for deferring service of two meridional lines in fiscal year 2021.

As of September 2020, the PIRATA array has 3 moorings not transmitting data, 3 moorings confirmed to be currently adrift. 10 (out of 18) PIRATA surface moorings are reporting less than 70% data return over the past month. We anticipate this overall health of the PIRATA array to continue to decline because many of the moorings are well past their 1 year design life. There is some good news on the horizon with two of the three PIRATA cruises being scheduled for PIRATA maintenance in Oct/Nov 2020 and Feb/Mar 2021.

As of September 2020, the RAMA array has 3 confirmed drifting moorings. There are 2 additional RAMA moorings that are not reporting data or positions. 7 (out of 20) of the actively maintained surface moorings in RAMA are reporting less than 70% data returns in the past month. We anticipate this overall health of the RAMA array to continue to decline because many of the moorings are well past their 1 year design life. There are seven cancelled or postponed RAMA cruises that have not been rescheduled and are pending due to COVID-19 restrictions.

An existing challenge for NOAA is managing a pending technology obsolescence of components within the TAO buoy payload. To mitigate the impact of this risk NDBC is initiating a project to refresh the existing TAO buoy technology. PMEL is also evaluating new buoy data acquisition technologies. The first prototype deployment near Hawaii was recently recovered and buoy data intercomparison will be evaluated when the instruments are received at PMEL.

The Tropical Pacific Observing System 2020 (TPOS 2020) is an international project under GOOS for review of the observing system. TAO was originally designed in the 1980s based on 1980s science issues and largely on techniques from that era. The objectives of the TPOS 2020 are to redesign and refine the TPOS to better observe ENSO and advance scientific understanding of its causes, to determine the most efficient and effective observational solutions to support prediction systems for ocean, weather and climate services, and to advance understanding of tropical Pacific physical and biogeochemical/ecosystem variability and predictability. TPOS 2020 continues to make progress on its objectives. Two AGU sessions on Tropical Pacific research and observations related to TPOS 2020 will be held during the American Geophysical Union Fall Meeting. The sessions are titled: “Towards improvement in process understanding and modeling of the Tropical Pacific” (Session: 104660) and “Application of In Situ and Remote Sensing Technology to Understanding Tropical Pacific Climate Variability” (Session: 104749). Progress is also being made to evaluate options for the western Pacific moorings and there are plans being drafted to intercompare sensors from the so called Ding array proposed by the State Oceanic Administration (SOA) of China. This proposed Ding array is described in greater detail in the TPOS 2020 Second Report (<https://tpos2020.org/project-reports/second-report>).

The 2 TRITON moorings at 0°, 156°E and 8°N, 137°E and ADCP mooring at 0°, 156°E will be retired and no longer maintained following the JAMSTEC cruise planned in late 2021.

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**Annex (optional)**

**Status maps and graphics**









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