**Report by the DBCP Action Group**

**Tropical Moored Buoy Implementation Panel to the**

**Thirty-SEVENth session of the DBCP (DBCP-37)**

*(Virtual session, 08-11 November 2021)*

**1) Summary**

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| **Name of Action Group** | **Tropical Moored Buoy Implementation Panel (TIP)** |
| **Date of report** | 01 October 2021 |
| **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 (TAO), a central component of the ENSO Observing System, deployed specifically for research and forecasting of El Niño and La Niña; TRITON retired in 2021. * The Prediction and Research Moored Array in the Tropical Atlantic (PIRATA) * The Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) |
| **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 20°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:** 55 real-time moorings in TAO  (Final 2 TRITON buoys retired in June 2021)  **Tropical Atlantic Ocean:** 18 real-time moorings in PIRATA  **Tropical Indian Ocean:**  28 real-time moorings in RAMA |
| **Chairperson/Managers** | Dr. Mike McPhaden, PMEL, USA, Chairman  Dr. 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>  <https://incois.gov.in/portal/datainfo/buoys.jsp> |
| **Meetings**  *(meetings held in 2020/2021; and planned in 2021/2022)* | * DBCP-36, virtual session, Oct 2020 * PIRATA-24 annual meeting, 10-14 May 2021 * Workshop on Tropical Pacific Observing Needs, virtual session, 23-26 May 2021 * DBCP-37, virtual session, Nov 2021 * AGU Fall Meeting 2021, New Orleans, LA, USA, 13-17 Dec 2021. * AMS Annual Meeting 2022, Houston, TX, USA (and virtual), 23-27 Jan 2022 * Ocean Sciences Meeting 2022, Honolulu, HI, USA, 27 Feb – 4 Mar 2022 |
| **Current status summary** *(Oct-2021)* | ***Pacific Ocean TAO:***   * 42 of 55 TAO moorings reporting data * 4 of 4 TAO ADCP moorings currently deployed * 0 of 0 TRITON moorings. The final two TRITON moorings at 0°-, 156°E and 8°N, 137°E as well as the ADCP mooring at 0°-, 156°E were retired in June 2021.   ***Atlantic Ocean PIRATA:***   * 11 of 18 PIRATA moorings reporting data * 2 of 2 PIRATA ADCP mooring currently deployed   ***Indian Ocean RAMA:***   * 3 of 28 RAMA surface moorings reporting data * 4 of 4 RAMA ADCP moorings currently deployed |
| **Challenges/Opportunities/Risks** *(intersessional period- highlighting the impact of COVID19 and mitigation plans)* | The COVID-19 global pandemic has created significant challenges for maintaining the tropical moored buoy arrays. There have been particularly notable losses in the Indian Ocean. In 2020 and 2021 there were no RAMA cruises completed. This has resulted in extended deployments well past the mooring design life and as a result there have been significant data losses as well as loss of assets. NOAA/PMEL is working with NOAA and partner institutions to try to schedule cruises for 2022. Delays in cruise scheduling present a significant risk to the tropical moored buoy arrays.  The final two TRITON moorings at 0°-, 156°E and 8°N, 137°E as well as the ADCP mooring at 0°-, 156°E were retired in June 2021.  The Tropical Pacific Observing System 2020 project (TPOS 2020) has published the third & final TPOS-2020 Report in Aug 2021 (<http://tpos2020.org>). This report provides an update in progress on: BGC observations, prediction modeling, data management/access, backbone array, and connection to subtropics via western boundary currents. “WIGOS Pre-operational Regional Pilot” is the next incarnation of TPOS-2020 as it transitions to resourcing for the pre-operational phase. |
| **Summary of plans for 2022** | **TAO:** Maintain 55 TAO mooring array.  **PIRATA:** Maintain 18 mooring array.  **RAMA:** Maintain 20 real-time surface moorings in the array if cruise scheduling is possible during ongoing pandemic. |

**2 Deployment plans for 2022**

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

**Pacific Ocean:**

* Winter/Spring 2022 (125W/140W) , 14 moorings and 1 ADCP mooring
* Summer 2022 (95W/110W) , 14 moorings and 1 ADCP mooring
* TBD 2022
* TBD 2022

**Atlantic Ocean:**

* Nov/Dec 2021 (0°N - 21°N, 23°W -38°W), 4 surface moorings (NOAA Ship Ronald H. Brown)
* Feb/Mar 2022 (8°S - 19°S, 30°W - 34°W), 6 surface moorings and 2 ADCP mooring (R/V Thalassa)
* TBD 2022 (14°S - 15°N, 30°W -38°W), 8 surface moorings (Brazil Ship TBD)

**Indian Ocean:**

* Dec 2021/Jan 2022 (4°S,67°E; 8°S,67°E; 8°S,67°E ADCP; 12°S,67°E), 3 surface moorings and 1 ADCP mooring (R/V Isabu)
* TBD 2022 (90°E), 3 surface moorings and 1 ADCP mooring (R/V Baruna Jaya)
* TBD 2022 (67°E), 6 surface moorings and 1 ADCP mooring (R/V Sagar Nidhi)
* TBD 2022 (80.5°E), 5 surface moorings and 1 ADCP mooring (R/V Sagar Nidhi)
* TBD 2022 (90°E to 95°E), 2 surface moorings (R/V Baruna Jaya)
* TBD 2022 (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, the new MOES RAMA-OMNI data portal launched in 2021, 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))

* MOES (<https://incois.gov.in/portal/datainfo/buoys.jsp> )

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**

The COVID-19 global pandemic has created significant challenges for maintaining the tropical moored buoy arrays. There have been particularly notable losses in the Indian Ocean. In 2020 and 2021 there were no RAMA cruises completed. This has resulted in extended deployments well past the mooring design life and as a result there have been significant data losses as well as loss of assets. NOAA/PMEL is working with NOAA and partner institutions to try to schedule cruises for 2022. Delays in cruise scheduling present a significant risk to the tropical moored buoy arrays.

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