TPOS2020: TROPICAL PACIFIC OBSERVING SYSTEM FOR 2020

After the partial collapse of the TAO/TRITON array, building a renewed, integrated, internationally-coordinated and sustainable observing system in the Tropical Pacific, meeting both the needs of climate research and operational forecasting systems.

By S. Cravatte[(1)], A. Ganachaud[(2)], B. Dewitte(2), F. Hernandez[(3)]

[1] IRD/LEGOS, Nouméa, New Calédonia
[2] IRD, LEGOS, UMR5566 CNRS-CNES-IRD-Université de Toulouse III, France
[3] IRD/LEGOS/Mercator Océan, Ramonville St Agne, France

Abstract

This paper presents the new international TPOS2020 project: why it has been established, what are its scientific objectives, its proposed organization, governance, and what the expected outcomes are. It is aiming at informing Coriolis, Mercator Océan, and the operational oceanography communities, all concerned, and involved in generating interest and contributions to the project. Building upon its scientific activities in the Pacific and the surrounding countries, the French community is willing to take an active role in this international project.

The TPOS 2020 Project is a focused, finite term project, which began in 2014 and will be completed in 2020. It will evaluate, and where necessary provide guidance, to change all elements that contribute to the Tropical Pacific Observing System (TPOS) based on a modern understanding of tropical Pacific science. Learning lessons from the great success-and finally partial collapse- of the TAO/TRITON array, the project objective is to build a renewed, integrated, internationally-coordinated and sustainable observing system in the Tropical Pacific, meeting both the needs of climate research and operational forecasting systems.

The scientific objectives are:

- To redesign and refine the TPOS to observe El Niño Southern Oscillation (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,
- To advance understanding of tropical Pacific physical and biogeochemical variability and predictability.

TPOS2020 is coordinated by a steering committee with task teams and working groups working on specific aspects of the observing system. Since much of the use and benefit of TPOS data will be achieved through model assimilation and syntheses, the operational modeling centers are considered key partners. The TPOS2020 project also opens partnerships with other global ocean observing communities: the meteorological community, and the coastal and regional ocean communities.

TPOS 2020 embraces the integration of complementary sampling technologies; it will consider the different observing system components as an integrated whole, targeting robustness and sustainability, along with a developed governance and coordination.

Historical background

Establishment of the Tropical Pacific observing system, 1985-1994

The tropical Pacific is home for the ENSO cycle, the dominant interannual climate signal on Earth. ENSO is an oscillation of the ocean-atmosphere coupled system between anomalous warm (El Niño) and anomalous cold (La Niña) conditions in the central-eastern equatorial Pacific. It impacts the weather anomalies, the frequency and intensity of tropical cyclones, the marine and terrestrial ecosystems and the fisheries. Through atmospheric teleconnections, its environmental and socio-economic impacts are felt worldwide, and the importance of its prediction is of prime importance to many countries around the world (Harrison et al., 2014).

The El Niño event of 1982-83, neither predicted nor detected, highlighted the need for real-time data, to help prediction, detection and understanding of the phenomenon. It was the impetus for the establishment of the international Tropical Ocean/Global Atmosphere (TOGA) program, and the original development of the Tropical Pacific observing system. One of the major achievements of TOGA (1985-1994) was the development of the Tropical Atmosphere/Ocean (TAO) array, the backbone of the observing system, consisting of 70 moorings in the equatorial band transmitting oceanic and atmospheric data in real time (McPhaden et al., 1998). This array, developed with support mainly from the United States, France, and Taiwan, took a decade to built **(Figure 1)**. In the 80s-90s, France (IRD) took an active part in the array design, deployment and maintenance. The french team in New Caledonia was at the forefront of designing and supporting the TPOS, and conducted cruises along the 165°E meridian (Delcroix and Eldin, 1995). In 2000, the TAO array officially became the TAO/TRITON array, with sites west of 165°E occupied by Triangle Trans-Ocean Buoy Network (TRITON) buoys maintained by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), and moorings east of 165°E maintained by the US National Oceanic and Atmospheric Administration (NOAA), with a dedicated ship, the Ka'imimoana.

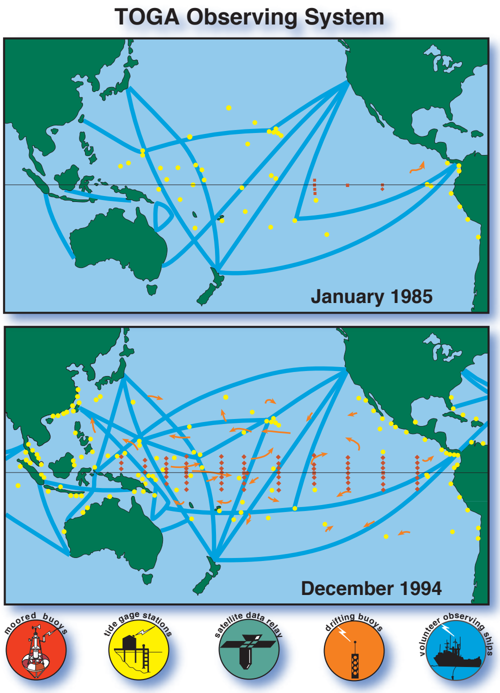


Figure 1: From McPhaden et al., (1998). The in situ Tropical Pacific Ocean Observing System developed under the auspices of the TOGA program. (top) The observing system in January 1985 at the start of TOGA; (bottom) the observing system in December 1994 at the end of TOGA. The four major elements of this observing system are (1) a volunteer observing ship expendable bathythermograph program (shown by schematic ship tracks); (2) an island and coastal tide gauge network (circles); (3) a drifting buoy program (shown schematically by curved arrows); and (4) a moored buoy program consisting of wind and thermistor chain moorings (shown by diamonds) and current meter moorings (shown by squares). By December 1994 most measurements made as part of this four-element observing system were being reported in real time.

Great success of the observing system 1994-2012

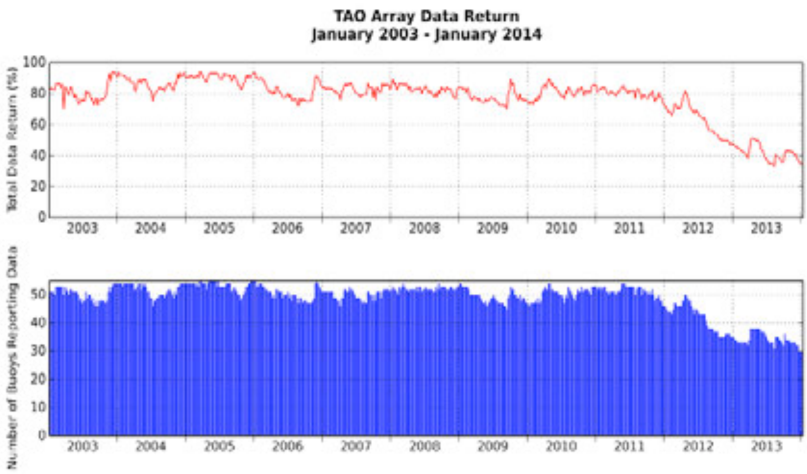
When it was first established, the primary rationale for the observational system was to improve description, understanding and prediction of seasonal to interannual variability in the tropical Pacific. In fact, the TAO/TRITON array's value, complemented by other sources of data, extended well beyond seasonal forecasting. Tremendous progress has been made on our understanding of the Tropical Pacific since the beginning of the TOGA program, even if many unknowns still remain. Oceanic and atmospheric data collected were used for a broad range of applications and process studies, and lead to the discovery and improved description of many processes important for the coupled system, but also for chemical and biogeochemical oceanography, studies of aerosols or meteorological phenomena, among others.

This observing system still continues to support routine forecasting systems and research. It also benefits to operational oceanography and ocean forecasting centers. In the past years, this community has been conducting various Observing System Experiments (OSE's) in order to measure the impact of its different components, TAO/TRITON being part of this assessment (Mercator Océan has carried out one specific OSE's, Rémy, pers. comm. 2015) (see also Lea et al., 2014, Fujii et al., 2015). Corresponding networks were developed in the tropical Atlantic (PIRATA) and Indian Oceans (RAMA) during and after TOGA, contributing to seasonal forecasts and to improved knowledge of climate variability in these regions.

Partial collapse of the TAO/TRITON array, 2012

20 years after the end of TOGA, sustaining a TPOS is proving challenging, in particular the TAO/TRITON array of moored buoys. In 2012, the retirement of the Ka'imimoana (not replaced, due to US budget cuts) led to a major reduction in data returns for the TAO part of the array. Since then, the TAO array has partially collapsed (Figure 2a) and data return dropped to around 40% in 2013, obscuring a large part of ENSO-related measurements. JAMSTEC has also begun to withdraw some of its TRITON moorings. These withdrawals interrupted times series of more than 30 years. Long time series are needed to understand decadal variability-which is large in the Pacific-, such as the Pacific Decadal Oscillation (PDO), climate change and how they interact with ENSO.

This partial collapse also highlighted the vulnerability of this observational array that underlies the capability for seasonal forecasting around the globe. An observational system relying too much on one nation, or one instrument, is at risk. An example in given in Figure 3, showing comparison between the objective analysis (without ocean model) and data assimilation results for two periods: in 2010, and in August 2013, when the distribution of data from the TAO array becomes very sporadic in the central and eastern equatorial pacific. It shows the larger dispersion among the objective analyses in 2013 compared to 2010 resulting from the lack of TAO/TRITON array data (Fujii et al., 2015).



The exact locations of TRITON buoys

Feb. 8, 2015

Location	Location (WGS84)		Date(yyyy/mm/dd)
	Lat.	Long.	
8N156E			operation stopped since 2014
5N156E			operation stopped
2N156E	02-02.33'N	156-01.22'E	30/12/2014
EQ156E	00-01.05'N	156-02.53'E	28/12/2014
2S156E	02-01.03'S	155-57.47'E	26/12/2014
5S156E			operation stopped
5N147E			operation stopped since 2014
2N147E	02-04.57'N	146-56.98'E	06/01/2015
EQ147E	00-03.58'N	147-00.65'E	08/01/2015
8N137E	07-39.10'N	136-41.96'E	17/01/2015
5N137E	04-51.90'N	137-16.22'E	13/01/2015
2N138E	02-04.05'N	138-03.88'E	12/01/2015
EQ138E			operation stopped since 2013
8N130E			operation stopped since 2013
2N130E			operation stopped since 2013

Figure 2: Left: TAO array data return (upper) and number of ATLAS buoys reporting data (bottom), between 2003 and January 2014. Source: Mike McPhaden, NOAA/PMEL, USA. Right: status of the TRITON array, in February 2015. Source: Ken Ando, JAMSTEC, Japan.

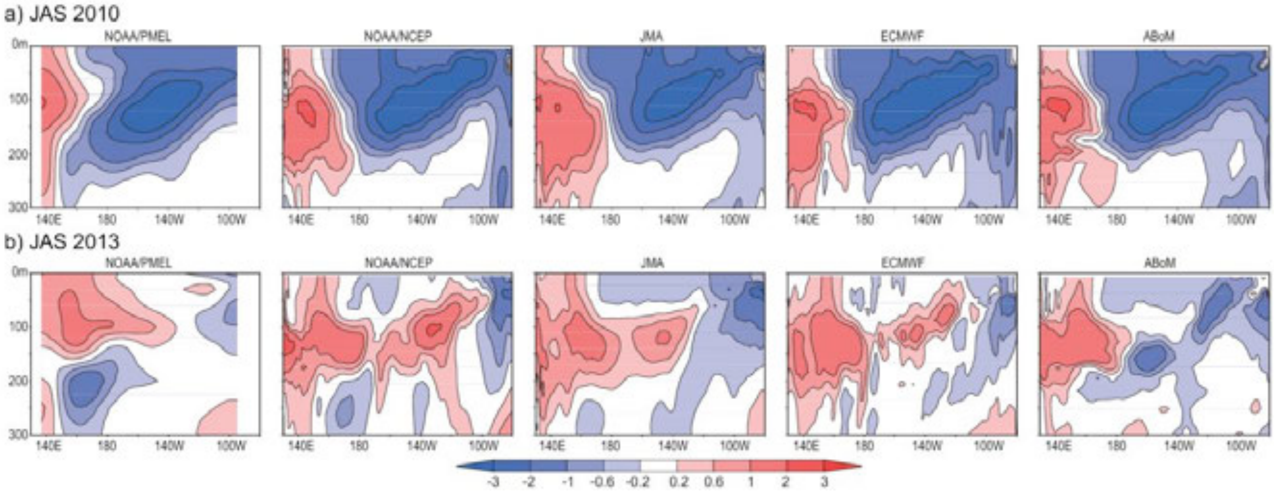


Figure 3: From Fujii et al., 2014 Temperature anomaly (unit: °C) distribution averaged in a) July-September 2010, and b) July- September, 2013 in the equatorial vertical section in the Pacific in the objective analysis from the TAO/TRITON data produced by NOAA/PMEL and the operational DA results of NOAA/NCEP, JMA, ECMWF, ABoM. The anomaly is calculated as the deviation from the WOA09 for the objective analysis, and those from the monthly climatology of each system in 1989-2007 for the DA results.

TPOS Workshop in January 2014, La Jolla, USA

In January 2014, NOAA and JAMSTEC, in collaboration with the Ocean Observations Panel for Climate (OOPC), convened a review of the TPOS, through a Workshop and associated White Papers (see “information and contacts” section). The workshop was attended by 65 invitees from 13 countries and 35 institutes. This led to immediate actions to address the deterioration in the observing system. A key outcome was the recommendation to establish a TPOS 2020 Project, to achieve a significant change between now and 2020 in all elements that contribute to the Tropical Pacific Observing System. A Steering Committee (SC) was formed, consisting of 15 members from seven nations throughout the Pacific. France is represented because of its interests and its active research on the Tropical Pacific and the upwelling system of Peru and Chile, and the IRD center in New Caledonia. The SC first met in October 2014; it reaffirmed the goals set forth for the TPOS2020 project and began the planning required for a successful implementation of the Project. The rest of this paper will detail these recommendations and plans.

TPOS2020 project: why do we need a renewed observing system?

A more modern consideration of requirements, meeting both the research and operational forecasting needs

Our understanding of Tropical Pacific variability and predictability has advanced to a point where a fresh articulation of observational requirements and system design is needed.

The ocean-atmosphere system appears to be coupled on many time and space scales that matter for ENSO (Kessler at al., 2014). The key role of stochastic forcing on the development and irregularity of El Niño events was highlighted; the decadal and longer-term variability was recognized to modify the background state and modulate ENSO amplitude and frequency. High temporal resolution time series from the TAO/TRITON moorings have also underlined the importance of the tropical instability waves, of the diurnal cycle, and of the near surface stratification for a good understanding of the coupled system. The observing system also helped to reveal surprises such as the great diversity of ENSO, and the occurrence of so-called “Modoki El Niño”. The recognition that ENSO is modulated at long timescales calls for sustaining an observing system in order to better address climate change issue.

The spatial extension of the TPOS should also be reconsidered, since experimental projects pointed out the demand to expand the observing system to the western Pacific (for example, the western boundary currents, key elements for the recharge/discharge of the equatorial band, may be important to monitor routinely) and to the eastern Pacific, the sites of key processes for the growth of strong El Niño event (Takahashi et al., 2014)

In addition, there has also been an evolution in the complexity of analysis, modelling and predictions systems. Besides seasonal forecasting, operational centers now develop sub-seasonal and decadal forecasts (Balmaseda et al., 2014), and ocean forecasts. TPOS 2020 will consider these new requirements and serve the needs of these forecasting systems.

An integrated observing system

TAO/TRITON was conceived and implemented more than 2 decades ago. In the last two decades, new in situ and satellite observational technologies have emerged, and became important components of the observing system. In particular, the international Argo array of profiling floats now provides broad-scale global observations of temperature and salinity down to 2000 m, and allows resolving many processes, including intraseasonal equatorial waves (Roemmich et al., 2014). Satellite observations of sea surface temperature, sea surface height and winds and sea surface salinity measurements from recent satellite missions have all emerged since TOGA (Lindstrom et al., 2014). Surface drifters, semi-autonomous platforms, tide gauges, repeated hydrographic cruises, sea surface salinity measurements onboard research and commercial ships and XBT deployments are also important components of this system **(Figure 4)**.

A strong general message of the La Jolla Workshop was that the observing system would benefit from being considered more as an integrated whole, including the aforementioned, modeling and data integration, as well as modern in situ technologies. It was also acknowledged that some redundancy in the system is essential to mitigate risks and improve quality control through redundancy.

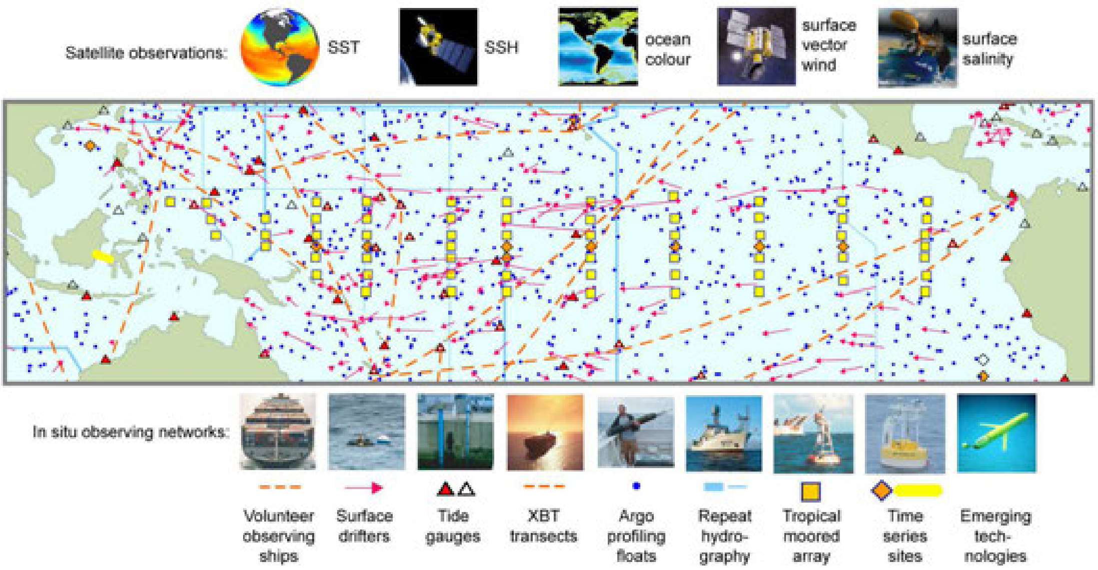


Figure 4:
Tropical Pacific Observing System: current observations

Organization and expected outcomes

A Steering Committee is responsible for oversight and coordination, and Task Teams (TT) were appointed to organize the activities agreed on and report to the steering committee. These are:

- **the "Backbone TT"**, to evaluate and improve the backbone of the observing network
- **the "Planetary Boundary Layers" TT**, to elaborate the scientific need and feasibility of observing the planetary boundary layers, including air-sea fluxes, near surface processes and diurnal variability
- **the "Modelling and Data assimilation" TT**, to consider approaches to advancing modelling, data assimilation and synthesis so that observations can achieve their fullest impact.
- **the "BioGeoChemistry" TT**, to develop rationales, requirements and strategy for biogeochemical observations

The "Eastern Pacific" and "Western Boundary" working groups, to evaluate approaches to observation of the eastern and western boundary regions, are also in construction, and may evolve as Task teams too. In addition, a working group on Time series and the climate record will consider the possible criteria for assessing the relative values of fixed-point time series to the Tropical Pacific Climate record: the idea is to identify "key" sites, and progress toward a new TPOS in a way that minimizes the scientific loss of interrupting part of the Tropical Pacific ocean data record.

Objectives of the Task teams

Backbone Task Team

The "backbone" terminology emphasizes that there should be a core of the observing system that anchors and underlies all other pieces of the system; some of which may be implemented for a limited time in a specific region. Basically, it will be a mix of moorings, Argo floats, and satellites. In and near the equatorial waveguide, higher temporal and spatial resolution of temperature, salinity, carbon system variables and currents are needed than in many extra-equatorial areas. Similar considerations probably apply to the near-surface layer.
The backbone will be designed to maintain consistent and well-understood sampling rates and scales that allow for the detection of climate variability and climate trends.
The major objective of this Task Team is to recommend a feasible plan for achieving a new configuration of the observing system. Sampling for the backbone observing system aims at:

- Observing and quantifying the state of the ocean, on time scales from weekly to interannual/decadal;
- Providing data in support of, and to validate and improve, forecasting systems
- Supporting calibration and validation of satellite measurements
- Advancing understanding of the climate system in the tropical Pacific, including through the provision of observing system infrastructure for process studies
- Maintaining and, as appropriate, extending the tropical Pacific climate record.

Modelling and Data Assimilation Task Team

Although modelling of the tropical Pacific and seasonal forecasting using coupled atmosphere ocean models have improved since the end of the TOGA experiment, much remains to be done, as models continue to be plagued by large errors (Balmaseda et al., 2014; Fujii et al., 2015). The La Jolla Workshop identified inadequacies in models and in data assimilation as the major limiting factors for effective use of TPOS observations in seasonal-to-interannual predictions and the accuracy of related products, including both the analysis of the ocean state and the predictive skill of coupled model forecasts. Inadequacies could be model errors associated with either the atmospheric or oceanic component of the coupled models, or could be related to data assimilation methodologies. Consequently, a focused activity on the coordination of multi-model evaluations is presently carried on: Fujii et al (2015) offers a summary of existing OSEs studies measuring the impact of TAO/TRITON in data assimilation systems, for ocean short term forecast, seasonal, decadal prediction, but also for validation of operational systems. Despite the fact that OSE's results depend on the type of data assimilation, most studies indicate that temperature and salinity analyses are impacted by moored observations, in complement of Argo profiles. These ongoing results give indication that the loss of TAO/TRITON would degrade the forecasting skills of these operational centres. In response of TPOS2020, this operational oceanography and data assimilation community under the framework of CLIVAR/GSOP and GODAE OceanView, is also starting a real time intercomparison of ocean reanalyses and operational analyses on monthly basis (Xue, Fujii, Balmaseda, pers. comm., 2015), where eight operational forecasting systems (NCEP, ECMWF, JMA, GFDL, NASA, Bureau of Met., UK-Met, and Mercator Océan) provide temperature and heat content fields for multi-model and ensemble prediction and estimation, focusing also on assessing the impact of the different type of observations in the Tropical Pacific.

Considering these studies, the objectives of this task team are:

- To develop strategies for coordinated modelling and assimilation activities for designing and planning the future TPOS observing systems,
- To identify pathways that will contribute to improved understanding of systematic errors and subsequent model improvements, especially through promotion of joint activities with other bodies that have mandates to improve models.
- To contribute modelling and data assimilation insights into the identification of observational requirements.
- To provide guidance on the assessment of the impact of modelling and assimilation, including through systematic continuous evaluation (metrics and process-oriented diagnostics), OSEs, and OSSEs, of the TPOS and its design, especially using the multi-model approach.
- As appropriate, recommend strategies for model initialization that will promote the efficient use of TPOS information.
- To provide recommendations on improving coordination among centers currently engaged in ocean analysis and prediction towards assessment of TPOS and its influence on predictions.

Planetary Boundary Layers Task Team (Coupling, Interaction, Processes)

Improved monitoring, understanding, parameterization and modelling of ocean surface (air-sea interaction) and near-surface processes have been identified as a priority for TPOS 2020 (Cronin et al., 2014). Many essential ocean and climate variables are now derived from a combination of satellite and in situ data. Supporting the observational needs of these synthesis activities is essential (e.g., GHRSST for SST). Thus satellite calibration/algorithm development and validation requirements along with product synthesis pathways need to be imbedded in the new TPOS 2020 design.
In addition, the importance of the diurnal cycle in modulating SST and air-sea exchange is now apparent. The parameterization of fluxes (and boundary layer processes) under different regimes (stable/unstable boundary layer, sea wave state dependency, etc.) also needs dedicated observations.
The task team will have, among others, the charge to:

- Formulate a practical observing strategy and technical sampling requirement to ensure comprehensive air-sea fluxes can be estimated at hourly or better resolution across a set of key ocean and climate regimes in the tropical Pacific, covering the full suite of state variables to estimate heat, moisture, and momentum exchanges, including through use of bulk formula.
- Develop recommendations about measurements that should resolve the diurnal cycle in the oceanic and atmospheric boundary layers.
- Consider whether a subset of regimes where direct eddy-correlation approaches might be used is feasible and of value.
- Liaise with the existing and developing ocean satellite and modelling community on efficiently meeting their present and future requirements for ocean surface data.

Biogeochemistry (BGC) Task Team

During the La Jolla Workshop, the need of integration of biogeochemical observations in TPOS to improve understanding of the tropical Pacific in the global carbon budgets and ocean productivity was highlighted (Mathis et al., 2014). This task team will begin with carbon biogeochemistry as its core scientific concern; it will consider primary productivity but not higher trophic levels (zooplankton to fish). The main objectives of the task team will be:

- To develop strategies and design plans for the biogeochemical contributions to the Tropical Pacific Observing System
- Determine the requirements, including time and space scales that should be resolved
- Provide a prioritized list of variables that will be measured as part of the BGC observing network.
- Provide guidance on implementation, including needed/potential new technologies and required process studies.

Approaches to observations in the western and eastern boundaries

In addition to the "backbone" observing system, the western and eastern boundary regions and the Indonesian Throughflow were identified as key regions that require specific observational system designs.
In the Western Pacific, several large regional projects already exist or are planned (e.g. the Southwest Pacific Ocean Circulation and Climate Experiment (SPICE), Indonesian Throughflow programs and the North Pacific Ocean Circulation and Climate Experiment (NPOCE) under the auspices of CLIVAR). The results of these experiments and others should be used to assess which observations need to evolve into sustained systems, and a group was formed to do the 'due diligence' at the moment.
The far Eastern Pacific has been recognized as a key region for ENSO since this is where the thermocline feedback is the most effective allowing for the development of strong events with large societal and ecological impacts in surroundings countries. Non-linear processes important for ENSO are

also at work there, which are still insufficiently documented. Additionally, meridional processes originating in the southeast Pacific associated with surface winds and heat ocean- atmosphere exchange, potentially connected to the coastal upwelling system, could penetrate into the equatorial eastern Pacific and affect ENSO (Takahashi et al., 2014). A task team will develop a regional research project to address these issues, and provide guidance for sustained observational networks that would be needed in the region.

Why should French community be part of it?

• Measurements of TAO/TRITON buoys, together with the more recent arrays of PIRATA buoys in the tropical Atlantic Ocean and RAMA in the Indian Ocean, are the keystone of observability in the tropics. They serve as reference for the majority of other datasets, satellite or in situ. Observations of moorings transmitted in real time are also used on a daily basis by the operational centers, by Mercator Océan and ECMWF.
French researchers are, and have always been, strongly involved in observations in the tropics. Since 1970, more than 100 french cruises have been organized in the South Tropical Pacific, and in the 80s and 90s, the French research community was among the prime drivers for TOGA and featured prominently in the big success stories. IRD in collaboration with Meteo-France, CNRS and IFREMER, provides financial, technical and logistic support for PIRATA. In addition, France has the leadership for observations of sea surface salinity onboard commercial vessels (ORE-SSS), and regularly contributes to deployment of Argo floats and drifters in the region.
• Monitoring the Pacific Ocean requires an international effort from all nations whose oceanographic fleets steam across the Pacific, as the main constraint is ship access to remote areas. The French presence in the TPOS-2020 coordination committees will open the possibility of (a minima) occasional contributions, e.g., Argo releases during cruises or transits; maintenance of met stations on buoys, instrument rescues etc.
• To assist the design of the future observing system, TPOS will require enhanced coordination across various centers engaged in ocean analysis and prediction. Impact or sensitivity studies in numerical simulations may be needed to evaluate the importance of the different observational networks. Mercator Océan has already been pursuing a series of “Observing System Experiment” studies, as part of GODAE OceanView and there has been an interest within the national community to expand this effort to adress issues relevant to TPOS2020 (cf. GMMC letter of intention on “Impact of observations in the tropical Oceans” (PIs: A. Ganachaud, F. Hernandez)) and contribute to this emerging international program.

Governance

TPOS 2020 will be managed and implemented within the context of existing and planned activities of the Global Ocean Observing System (GOOS); and in particular the activities of the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) which coordinates the implementation of many of the existing in situ networks.
Other critical partners include the Climate Variability and Predictability Project (CLIVAR) and its Global Synthesis and Observation Panel (GSOP) and GODAE OceanView. CLIVAR supports a number of research activities and projects relevant to TPOS2020, particularly with respect to modeling and process studies. GSOP aims at providing reliable estimation of the present and past ocean state, through ocean reanalysis synthesis in particular, for which past and future moored array high quality time series allow a consistent reconstruction of ocean parameters. The work of GODAE OceanView is relevant to the planned ocean prediction and observing system studies of the TPOS2020 project.
Four primary elements are included in the governance of the Project:

- A TPOS 2020 Steering Committee responsible for oversight and coordination. Chairs are Neville Smith (retired, Australia) and William Kessler (NOAA, PMEL, USA)
- A Resources Forum drawn from sponsors and responsible for coordinating resources.
- An Executive populated from the leadership of the above and responsible for reporting.
- A Project Office focused on coordination activities supported and resourced by the sponsors.

It is through these partnerships and governance structure that TPOS2020 will be able to fulfill its objectives.

Contacts and information

More information about the project, its partners, organization and outcomes can be found on the TPOS2020 official website: http://tpos2020.org/
The Terms of References for the Steering Committee and the different task teams are given.
This paper largely used material and sentences posted on this site, including the “prospectus” document.

The La Jolla 2014 Workshop Report, the white papers can also be downloaded on:
(http://tpos2020.org/tpos-2020-released-documents/ OR http://www.iode.org/index.php?option=com_oe&task=viewEventRecord&eventID=1383) and the oral presentations on (http://tpos2020.org/presentations/).

Sophie Cravatte (IRD/LEGOS, New Caledonia) is member of the Steering Committee and co-chair of the backbone task team.
Alexandre Ganachaud (IRD/LEGOS, Toulouse) is member of the backbone task team. He is also chair of the CLIVAR Pacific Panel.
Boris Dewitte (IRD/LEGOS) will be member of the Eastern Pacific Task team.
Fabrice Hernandez (IRD/LEGOS/Mercator Océan, Ramonville St Agne) is member of the Steering Scientific Group of PIRATA, co-chair of the Intercomparison and Validation Task Team of GODAE OceanView, and coordinating focused tropical ocean studies at Mercator Océan.

Acknowledgments

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References

Balmaseda, M., et al., (2014): Operational Forecasting Systems (White paper #4, http://tpos2020.org/tpos-2020-released-documents/)

Cronin, M., et al. (2014) Wind stress and air sea fluxes observations: status, implementation and gaps (White paper #11, http://tpos2020.org/tpos-2020-released-documents/)

Delcroix, T. and G. Eldin, 1995. Observations hydrologiques dans l'océan Pacifique tropical ouest. Campagnes SURTROPAC 1 à 17, de janvier à aout 1992; campagnes COARE156 1 à 3, d'aout à octobre 1992. Travaux et Documents Microédités 141, ISBN: 2-7099-1266-X; Editions de l'ORSTOM, Paris, 1995, 78 pages.

Fujii, Y., J.A. Cummings, Y. Xue, A. Schiller, T. Lee, M.A. Balmaseda, E. Rémy, S. Masuda, G.B. Brassington, O. Alves, B. Cornuelle, M.J. Martin, P.R. Oke, G.C. Smith, and X. Yang, Evaluation of the Tropical Pacific Observing System from the Ocean Data Assimilation Perspective, Quarterly Journal of the Royal Meteorological Society, 2015.

Harrison, D.E., et al. (2014): Some societal impacts of ENSO (White paper #2, http://tpos2020.org/tpos-2020-released-documents/)

Kessler, W.S., et al. (2014): ENSO Research: The overarching science drivers and requirements for observations (White paper #3, http://tpos2020.org/tpos-2020-released-documents/)

Lea, D.J., M.J. Martin, and P.R. Oke, Demonstrating the complementarity of observations in an operational ocean forecasting system, Quarterly Journal of the Royal Meteorological Society, 140 (683), 2037-2049, 10.1002/qj.2281, 2014.

Lindstrom, E., et al. (2014) Satellite views of the Tropical Pacific (White Paper #9, http://tpos2020.org/tpos-2020-released-documents/)

Mathis, J., et al. (2014) Tropical Pacific biogeochemistry: status, implementation and gaps (White paper #6, http://tpos2020.org/tpos-2020-released-documents/)

McPhaden M.J., et al. (1998) The tropical ocean-global atmosphere (TOGA) observing system: a decade of progress. J.Geophys.Res., 103, pp. 14169-14240.

Roemmich, D., et al. (2014) In situ temperature, salinity, and velocity observations (White paper #10, http://tpos2020.org/tpos-2020-released-documents/)

Takahashi, K., et al. (2014) Regional applications of observations in the eastern Pacific: Western South America (White paper #8a, http://tpos2020.org/tpos-2020-released-documents/)

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QUARTERLY

Newsletter

MERCATOR OCEAN

OCEAN FORECASTERS

SPECIAL ISSUE with Coriolis

While most Argo floats are deployed by research vessels, some are also deployed by the sailing community, through ship-based non-governmental organization or trans-oceanic races. It allows poorly sampled areas with no regular shipping to be sampled. Sailors got also involved in oceanographic science activities. An example of float deployment is given here (see Poffa et al., this issue) in the case of the 2015 Barcelona World Race where eight floats were successfully deployed in the Atlantic Ocean between 24° and 44° south.

Credits: © Barcelona World Race

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Please send us your comments to the following e-mail address: webmaster@mercator-ocean.fr