Reinvigorating Research on the Western Pacific Warm Pool – First Workshop.

Jaclyn N. Brown, Christophe Maes, Alex Sen Gupta, Richard Matear, Sophie Cravatte, Clothilde Langlais and other workshop participants.

The first workshop of the Western Pacific Warm Pool (WPWP) took place in Hobart, Australia, on 4-8th March, 2013. The main objective of the workshop was to revisit some of the fundamental mechanisms driving the dynamics of the WPWP, particularly at its equatorial eastern edge, to determine whether further research was warranted and what form this should take.

The WPWP was the topic of extensive research in the Tropical Ocean – Global Atmosphere (TOGA) – Coupled Ocean-Atmosphere Response Experiment (COARE) international programme (Webster and Lukas 1992). The program led to many papers characterising the WPWP and discussing the implications of its existence and behaviour. Picaut et al. (2001) reviews some of these findings and pointed out the importance of its eastern edge along the equator.

Defining the eastern edge

The edge is a region of zonal convergence and acts as a boundary between fresh, oligotrophic waters with high tuna catch and strong atmospheric convection to the west and salty, high pCO2 mesotrophic water to the east. As a result of long-term SST observations "... the 28°C isotherm has been used by many scientists as a practical compromise for the definition of the west Pacific Warm Pool" (Wyrtki 1989). It is apparent however that there is no one 'best' metric for defining the edge, rather a variety of metrics are necessary depending on application and where changes in the background state are occurring – see Table 1. While these metrics are all strongly correlated, they diverge at certain times (Picaut et al. 2001). The reason for this divergence is still not fully understood.

Variability of the WPWP

The WPWP has decadal variability (related to ENSO and the Pacific Decadal Oscillation) that needs to be accounted for when exploring long term trends (Zhang and Church 2012). The decadal variability may also alter the dynamics of the WPWP and hence the ENSO mechanisms.

Interannual variability dominates the zonal movement of the WPWP, while large meridional seasonal excursions are apparent (Kim et al. 2012).

Trends in the WPWP

Since 1955, different observations consistently show that the WPWP has significantly warmed and freshened. They also reveal a significant horizontal extension of the warm and fresh surface waters, an expansion of the warm water volume, and a notable eastward extension of its equatorial edge (e.g. Cravatte et al. 2009). The freshening has been suggested to be explained by the "wet get wetter paradigm", and has been attributed to anthropogenic climate change (Terray et al. 2012). Whether the east-west SST gradient has increased or not is still a matter of debate.

Barrier Layers

The region below the fresh surface lens in the WPWP and the base of the thermal mixed layer (Lukas and Lindstrom 1991) forms the salinity barrier layer (BL). The BL is primarily confined to the eastern edge of the WPWP (Bosc et al. 2009). Here the salinity stratification can affect the ocean budget: trapping the momentum of wind stress over a shallower mixed layer while suppressing the entrainment of cold thermocline water into the mixed layer. The potential for the BL thickness to influence ENSO onset was a research priority of TOGA-COARE, but its effect remains uncertain due to the lack of observations. Modelling studies however have suggested that the existence of a BL does alter heat build-up in the WPWP (Maes and Belamari 2011), and consequently the onset and variability of ENSO. A remaining question is whether realistic BL variability in models is essential for improving ENSO forecasts and future climate projections.

Primary Productivity

In the WPWP, surface nutrient concentrations are low, waters are very oligotrophic in its central part, and much of the biological activity occurs below the well-mixed surface layer (Le Borgne et al. 2011). This surface nutrient-depletion results from a lack of upwelling in the region and a deep thermocline which under average climatic conditions is located close to the lower limit (~ 80 m) of where light is sufficient for phytoplankton growth. Furthermore, the thermocline has a strong temperature gradient, which forms a natural barrier to the vertical supply of nutrients to the photic zone.

In addition to the large variations in the horizontal extent of the WPWP with ENSO, the vertical structure of the WPWP is also impacted. During El Niño, the thermocline can shoal to ~40 m, which increases the vertical supply of nutrients to the photic zone and increases primary productivity (Le Borgne et al. 2011). This ocean response becomes more complicated near the eastern edge of the WPWP where the presence of the BL can interact with the thermocline depth and the supply of nutrient into the photic zone. It would appear that there is a positive interaction because the region to the west of the edge of the WPWP is biologically productive and is targeted by skipjack tuna fishers (Lehodey et al. 2011).

Simulating the WPWP in CMIP5

The warm waters of the western Pacific are simulated too far west in almost all CMIP5 coupled climate models as an integral part of the cold tongue bias (Brown et al. 2012). New research presented at the workshop demonstrated that the 'fresh pool', defined by the strongest salinity gradient, is not as poorly simulated in coupled models as the 'warm pool' defined using a fixed isotherm (Brown and Langlais Submitted). However, the ability of the models to simulate this edge and its variability ranges widely across CMIP5 models. Surprisingly, even models with a very poor representation of the WPWP still often simulate a realistic Nino3.4 variability. This implies that their ENSO dynamics must be quite different to what is observed. Regardless of the simulation of the WPWP edge, models show a zonal structure to the warming pattern. There appears to be a lower rate of warming inside the warm pool than in the cold tongue to the east, in the 2050-2100 period under the RCP8.5 scenario (Brown and Langlais Submitted).

Need to understand the WPWP now and in the future:

- ***Coral bleaching***

The coral within the WPWP have been projected to be one of the first to suffer from an increased frequency of bleaching events under various climate change scenarios (Meissner et al. 2012). Due to a low temperature variability (no seasonality and low interannual variability), the coral reefs within the WPWP are projected to have the latest onset of severe bleaching risk in the Western Pacific, but the fastest rate of risk increase (Langlais et al. Submitted). These reefs are projected to be one of the first to suffer from an increased frequency of bleaching events. The fastest rate also implies that they would require a fastest adaptation.

Accurate temperature and acidification projections will aid management strategies.

- ***Tropical Tuna***

Tuna fisheries provide a substantial proportion of Gross Domestic Product to Pacific Island nations as well as food security (Bell et al. 2013). A strong link was found between the catch per unit effort (CPUE) of skipjack tuna and the edge of the WPWP(Lehodey et al. 2011). The causal links between ocean state, biogeochemistry, plankton and tuna behaviour are still being established.

Atmospheric interactions

We noted at the workshop a lack of understanding of the atmospheric links to the WPWP, particular through atmospheric fluxes, the MJO and WWBs.

This workshop was hosted by the CSIRO and was attended by a small international group of 20 scientists from Australia, Fiji, New Caledonia and France. Support for this workshop came from the Pacific Australia Climate Change Science and Adaptation Planning Program (PACCSAP) http://www.pacificclimatechangescience.org and the CSIRO Frohlich Fellowship program.

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Warm Pool Edge metric	Advantages	Disadvantages
SST threshold (28 - 30ºC)	• Important for atmospheric response, e.g. convection, tropical cyclones, intraseasonal variability including WWBs. • Satellite and in-situ data products readily available.	• Strongly affected by background warming • Inconsistent thresholds between models • Higher SST isotherms not always present • Decouples from other definitions in extreme events and at high-frequency time scales (such as diurnal cycle).
SSS threshold (34.2 to 35.2)	• More closely representative of dynamical edge.	• Same as above • Limited data availability, though new satellite products (SMOS & Aquarius) now available
Maximum SSS gradient	• Insensitive to background state • Representative of dynamical edge	• Limited data availability • Noisy and may be contaminated by high frequency variability
Isotherm fit to SSS gradient	• As above. • Useful for model intercomparison	• Isotherm needs to be revised with background warming
Density threshold (not common)	• Combines temperature and salinity changes	• Incorporates disadvantages of both temperature and salinity.
Convergence using hypothetical drifters	• Representative of 'dynamical edge' • Can use dynamic height, or satellite mean sea level as proxy	• Need to compute hypothetical drifters • May not converge in models due to the high sensitivity to background mean state • Limited observations and reliance on combined satellite estimates.
Chl-a (e.g. 0.1mg/m^3)	• Sharp front	• Limited to satellite record • May decouple from physical parameters.
Nitrate/pCO2	• Usually tracks the frontal zone	• Limited observations • May decouple from physical parameters.

Table 1. Metrics used to describe the edge of the Western Pacific Warm Pool and their advantages and disadvantages.

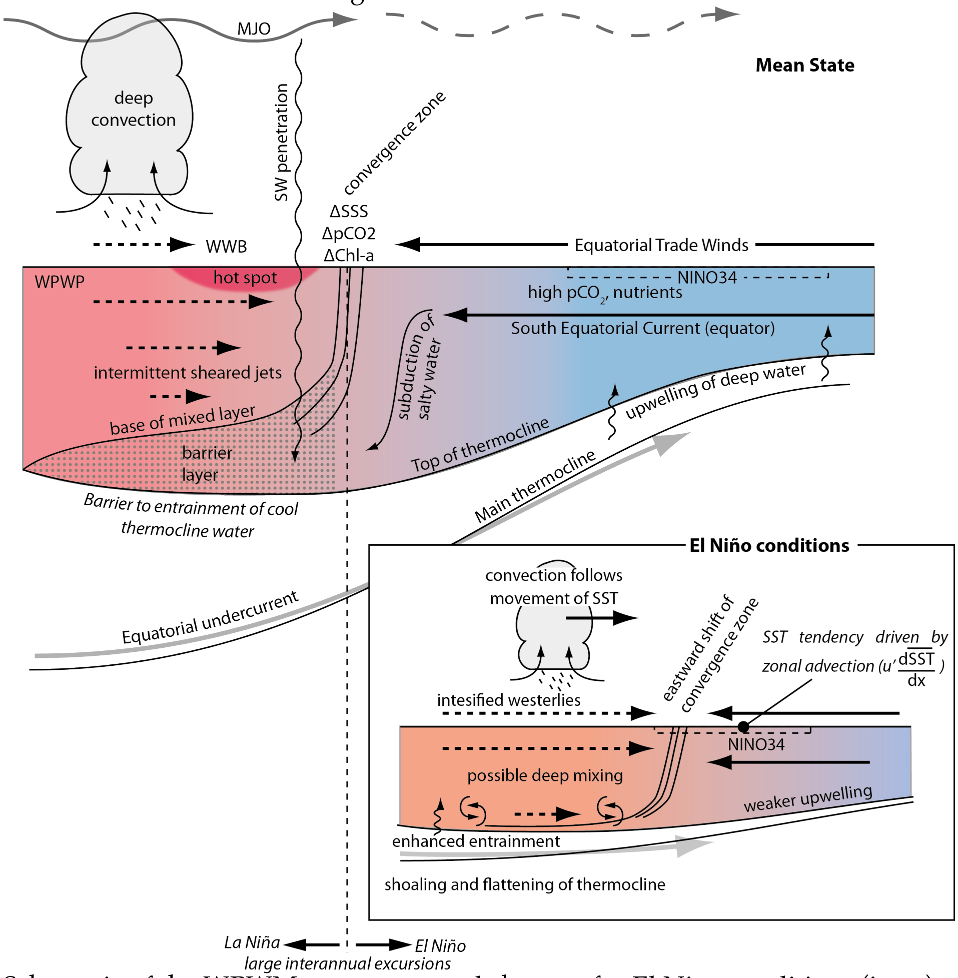

Figure 1. Schematic of the WPWM mean state and changes for El Nino conditions (inset)