OCEANIC EXTREME EVENTS ASSOCIATED TO CLIMATE CHANGE OFF PERU

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INTRODUCTION

The current national oceanographic monitoring and information system of Perú is mainly sustained by shipboard sections up to 100 nautical miles, nearshore fixed stations and stations along the coastline (Fig. 1). An upgrade of this system is in progress, involving (i) the use of gliders to record high-resolution and near-real time information of the coastal and subsurface circulation, as well as of the biogeochemical conditions in the upwelling cells; and (ii) the implementation of operational modelling for identification of oceanic extreme events associated to climate change (marine heat waves, harmful algal blooms and hypoxic-anoxic events).

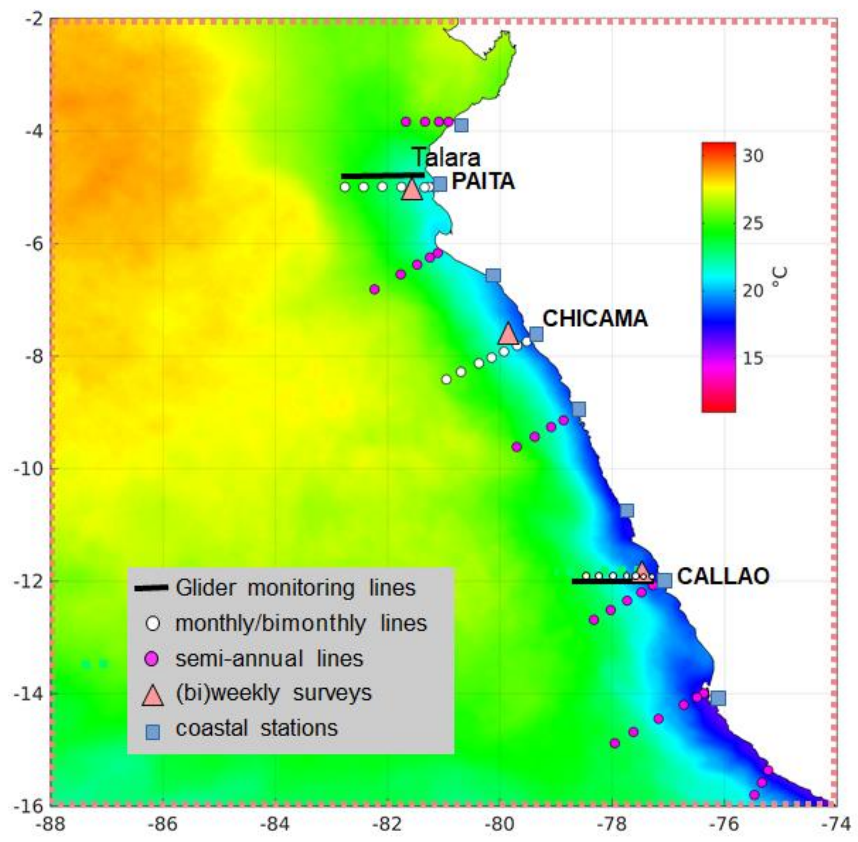

Figure 1. Shipboard monitoring lines at varying frequencies (circles), high-frequency fixed stations (triangles) and daily coastal stations (piers) along the Peruvian coast that compose the current monitoring system by IMARPE. Sustained glider monitoring lines are to be implemented off Talara, Northern Peru (04°30' S) and off Callao (12° S). Base map: SST distribution in March 2016 (MUR SST analysis) (D. Gutiérrez, pers. comm.).

MARINE HEAT WAVES

Satellite data

During the last decades occurrences of extreme warming of ocean temperatures (Marine Heatwaves, MHWs) have been regularly observed in the coastal ecosystem of the Peru-Chile eastern boundary upwelling system. Using satellite sea surface temperature, the characteristics and evolution of MHWs according to their duration have been investigated. Results show that, since 1982, long duration MHWs (> 100 days) have decreased in both occurrence and intensity while shorter events, which represent more than 90% of all the observed MHWs, have increased in their thermal impact as well as on the number of days they affect, particularly those spanning from 30 to 100 days (Fig. 2).

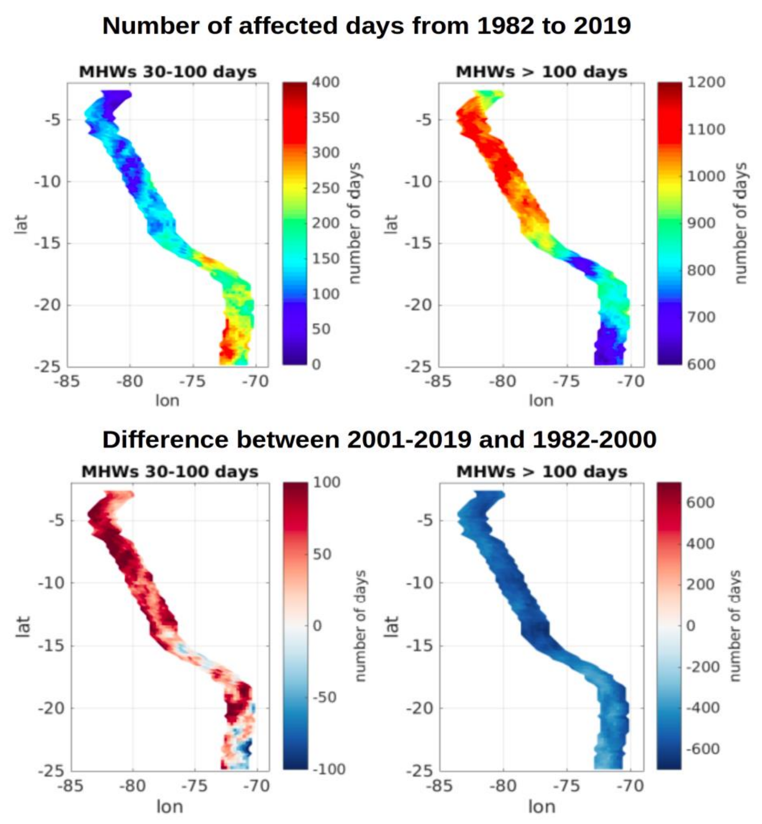

Figure 2. Number of affected days (top) and Difference between 2001-2019 and 1982-2000 (bottom) of short (30-100 days) and long (>100 days) MHWs (A. Pietri, pers. comm.).

Modelling

A multiannual hydrodynamic model (CROCO) simulation was performed in order to describe the main features of the MHWs during the two recent decades (2000-2019) in the NHCS. This hindcast experiment provided valuable information about the tridimensional characteristics of the MHWs, such as the fact that the maximum temperature anomalies are found at ~ 50 m depth, whereas the maximum duration is reached around the nominal depth of 100 m. Overall, surface MHWs of moderate high intensity occur frequently and last on monthly timescales. At intermediate depths (25-150 m), the intensity of MHWs is the highest and the duration the longest, but at a low frequency. Finally, within the deep layer (150-250 m), short-lived MHWs, on the scale of weeks, are of low intensity, but they appear at a high frequency (Fig. 3).

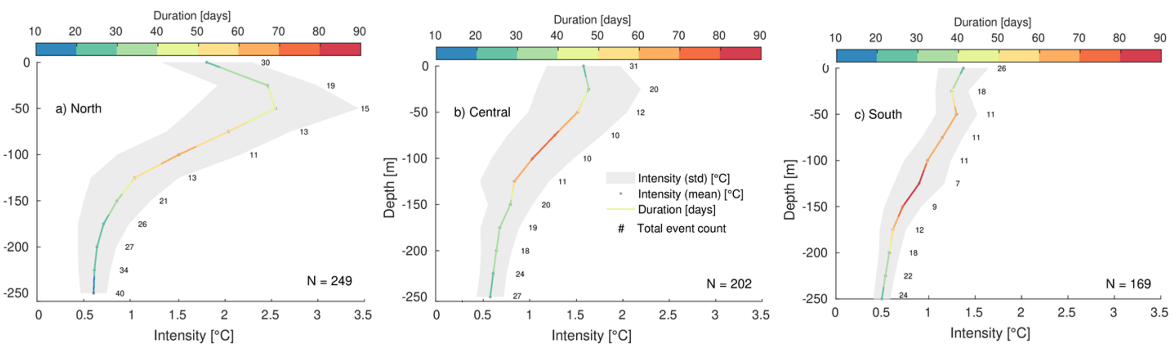

Figure 3. Mean vertical profiles of modeled MHW intensity (gray points) for: (a) northern (3-8°S), (b) central (8-13°S), and (c) southern domain (13-18°S). The color scale indicates the depth-varying duration in days. The gray shaded areas denote the std. dev. of the intensity related to the variability between all events. The floating numbers show the number of events at any depth, whereas N is the number of total valid points per domain (R. Mogollón, pers. comm.).

Throughout the recent two decades, it was found that surface MHWs are becoming significantly more intense (~1°C warmer per decade) and more persistent (~1 month longer per decade), particularly towards the northern domain. Over the central and southern domains, the occurrence of MHWs is becoming more frequent (~4 more events per decade), however with little variability in its intensity and duration. These findings expand our understanding of MHWs and their potential impacts on the Peruvian coastal region, revealing which regions are most susceptible to thermal stresses and indeed serve to improve MHWs predictability.

HARMFUL ALGAL BLOOMS

Harmful algal blooms (HABs) are proliferation of microscopic algae that have negative effects on marine environments and associated organisms, on food provisioning, tourism, economy and human health (Berdalet et al., 2016). In the Peruvian coast, mass mortality events of wild and cultivated species such as Peruvian scallops have been associated with the occurrence of HABs.
Through the study of HABs with historic information from IMARPE and the Organismo Nacional de Sanidad Pesquera (SANIPES), a historic HABs database was obtained with observations from 1980. To date, 956 bloom events have been reported.
In addition, information about the distribution of potentially toxic phytoplankton species in the Peruvian coast have been analyzed (Fig. 4), and the environmental conditions that favored the presence of toxic blooms caused by *Alexandrium ostenfeldii* in Paracas bay was obtained (Fig. 5). Results revealed that the critic period for blooms occurred mainly in summer and autumn.

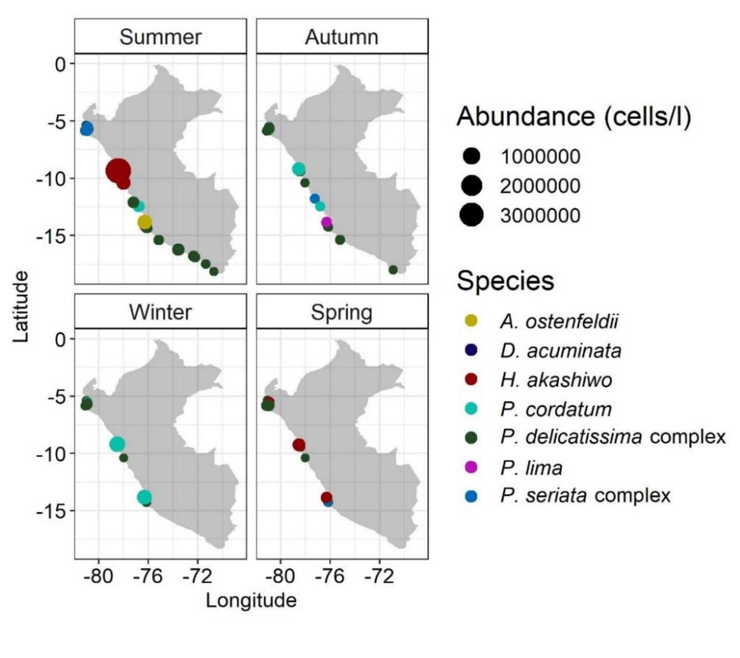

Figure 4. Maximum abundance of the main potentially toxic microalgae species (T. Cuellar, pers. comm.).

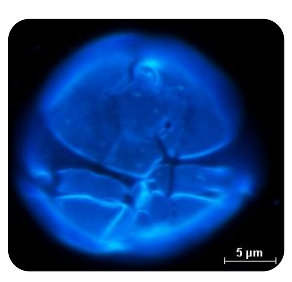

Figure 5. Microphotograph of *Alexandrium ostenfeldii*

HYPOXIC EVENTS

The occurrence of low oxygen conditions in marine coastal areas can be either natural or related to human influenced processes, triggering numerous effects in the ecosystem. In coastal Peruvian bays, mass mortality events have been related to the occurrence of HABs and hypoxic events. These nearshore areas are not only sensitive to the complex upwelling dynamics, but also to environmental stressors from anthropogenic activities. This is the case of Paracas Bay (15 °S), a traditional fish and shellfish farming area highly influenced by one of the most active upwelling centers of the Peruvian coast.

Through the installation of data loggers in Paracas Bay (Fig. 6) during September 2012 – February 2013 and March 2015 – December 2016, a retrospective database with hourly records of total dissolved oxygen was obtained. This allowed the quantification of hypoxic events in different locations of Paracas Bay. The frequency and duration of hypoxic events differed along the Bay and showed high variability. Overall, less frequent but longer events characterized the center and northwestern side, near the mouth of the Bay, with events lasting longer than 100 consecutive days. The southwestern and eastern side of the Bay is characterized by more frequent but shorter events. The analysis also revealed a clear pattern of longer events taking place during summer, contrary to winter and spring where hypoxic events are shorter and conditions are dominated by normoxia.

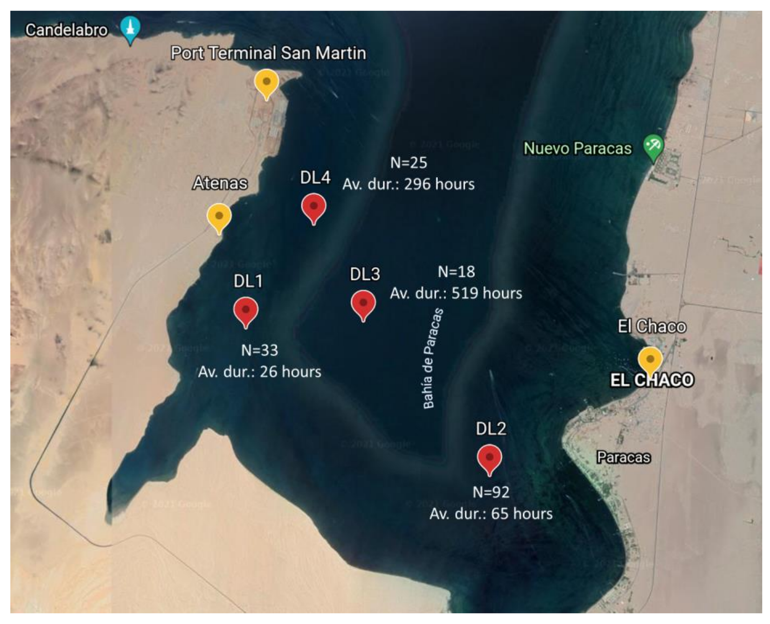

Figure 6. Map of Paracas Bay showing the position of the four data loggers (DL) deployed during September 2012 – February 2013 (DL1) and March 2015 – December 2016 (DL2, DL3, DL4). N = number of hypoxic events quantified. Av. dur: average duration of events (hours) (M. Igarza, pers. comm.).

CONCLUSIONS

Characterizing extreme events in the Peruvian Upwelling System will allow us to develop forecast models of these events as an early warning system (Fig. 7), which will benefit users to relocate scallop cultures or fishing grounds. Next steps, also include to analyse changes of these extreme events under climate change scenarios, using high resolution models dynamically downscaled to coastal bays.
Improvement of these models can be greatly achieved by assimilating data from gliders and satellites into CROCO-PISCES physical-biogeochemical model.

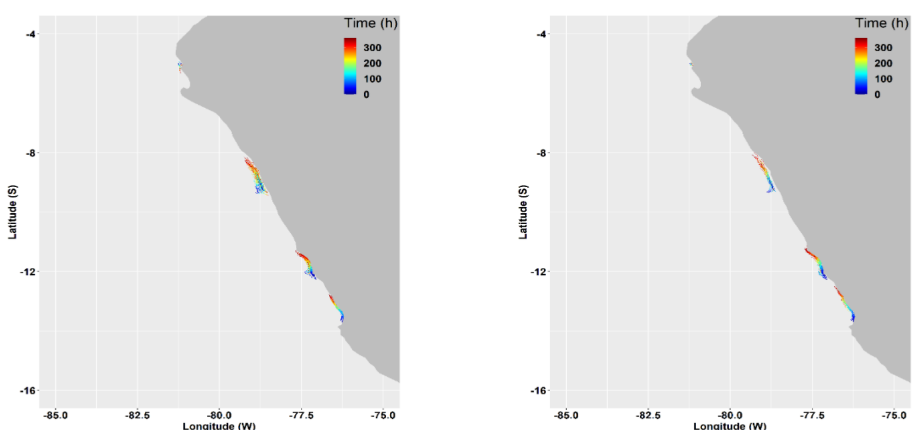

Figure 7. Harmful algal bloom forecasts using a lagrangian model during summer (left) and winter (right) (J. Flores, pers. comm.).

Acknowledgements

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