Impacts of the Pacific Equatorial Undercurrent on the Northern Peruvian Coast

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The Peruvian Hake Latitudinal Distribution in the bottom area.

2 different sceneries.

How this study began?
Study Area and Data used

Along the Equatorial Line

1. **Daily Current Velocity:**
   5 (147°E, 165°E, 170°W, 140°W and 110°W) ADCP. (TAO-NOAA)

2. **Daily Dynamic Height:**

Off Paita

1. **May/June Temperature, salinity and Oxygen:**
   in-situ observation data obtained from Paita Line along 5° S and between 81° 10W to 82° 25W over 75 miles during the autumn cruises (2000-2015) conducted by the Peruvian Sea Institute (IMARPE)
Methodology: Pacific Ocean

The Core velocity of the EUC is defined as the depth wherein the maximum current velocity locates in the daily climatology, and the Dynamic Range of the EUC at which the velocity reduces from the Core velocity by one standard deviation.

The proxy of the EUC transport (EUCut) is defined as the vertically integrated positive eastward flow within the Dynamic Range [m²s⁻¹].

Using the data of dynamic height η at 10 mooring stations, we computed the horizontal Pressure Gradient Force at the surface $P$ for the Equatorial Pacific.

Where, $g = 9.807$, the gravitational acceleration [ms⁻²], $x$ zonal coordinate, $p$ pressure, and $\rho$ density.
To identify the EUC water mass in the downstream North Peruvian Coast, we propose to define the EUCSCb water mass in the pycnocline at

$$\sigma_\theta = 25.3 \text{ to } 26.5$$

based on the probability density function (PDF), cumulative distribution function (CDF), the T-S properties and dissolved oxygen.

*The vertical sections of the in-situ data, including temperature, salinity and dissolved oxygen along Paita Line carried out on May-June were analyzed.*
The Core velocity of the EUC is defined as the depth wherein the maximum current velocity locates in the daily climatology.

Dynamic Range of the EUC at which the velocity reduces from the Core velocity by one standard deviation.
Results and Discussion

(a) The EUC zonal velocity [cms⁻¹] monthly climatology along the Equator at 147° E, 165° E, 170° W, 140° W and 110° W (magenta lines specify the Core and Dynamic range).

(b) EUC velocity transport [m²s⁻¹] monthly climatology (1991-2010) from 147° E to 110° W, showing higher values at the east side between March to July.

(c) The EUC Pressure gradient force [ms⁻²] monthly climatology (1991-2010) from 147° E to 95° W, while the highest values are presented at the middle of the Pacific between 180° W to 110° W.
The EUC zonal velocity [$\text{cms}^{-1}$] monthly anomaly along the Equatorial Line at 147° E, 165° E, 170° W, 140° W and 110° W.
Results and Discussion

(a) EUC velocity transport \([\text{m}^2\text{s}^{-1}]\) monthly anomaly from 2000 to 2015 along the Equatorial Line for 147° E, 165° E, 170° W and 110° W.

(b) The EUC Pressure gradient force \([\text{ms}^{-2}]\) monthly anomaly along the same region but for 147° E, 156° E, 165° E, 180° W, 170° W, 155° W, 140° W, 125° W, 110° W and 95° W.
The Probability Density Function (PDF) and the Cumulative Distribution Function (CDF).

(a) and (b) for the sigma-t at 0° N 147° E and 0N° 110° W within the Dynamic Range. black lines are the range of density which explain the 10 to 90 % presence of $\sigma_\theta = 25.35 - 26.60$ for 0° N 147° E and $\sigma_\theta = 24.85 - 26.25$ for 0° N110° W.

(c) and (d) the sigma-t as function of the EUC velocity transport within the Dynamic Range for the same mooring buoys.

Black lines are the range of density which explain the 10 to 90 % presence of $\sigma_\theta = 25.25 - 26.30$ for 0° N 147° E and $\sigma_\theta = 24.25 - 26.15$ for 0° N110° W.
Results and Discussion

Temperature, Salinity and Oxygen sections for the weak EUCSCb period along Paita Line (5°S). Black contour lines are $\sigma_\theta = 24.5$ to 26.5 isopycnals each [0.5 kgm$^{-3}$]. White contour lines are the isotherms, isohalines and iso-oxygens respectively.
Results and Discussion

Temperature, Salinity and Oxygen sections for the strong EUCSCb period along Paita Line (5°S). Black contour lines are $\sigma_\theta = 24.5$ to 26.5 isopycnals each [0.5 kgm$^{-3}$], while white contour lines are the isotherms, isohalines and iso-oxygens respectively.
Results and Discussion

The 26 Isopycnal and 15°C Isotherm depth (May–Jun) during the period 2000 to 2015 along Paita Line (5°S)

(The values correspond to the Paita continental slope stations)

The 120 meters and 150 meters depth were emphasized with blue and red dashed line respectively.
Results and Discussion

EUCSCb: Sigma-t and Salinity dominance values

(a) PDF and (b) CDF for sigma-t binned \([0.1 \text{ kgm}^{-3}]\).

The red dashed lines are the range of density which explain 10 to 90 % presence of \(\sigma_\theta = 25.25 - 26.5\) off Paita between 50 to 300 meters depth.

(c) the PDF and (d) CDF for salinity binned \([0.1]\) at the subsurface layer between 50 to 300 meter depth.

the salinity boundary of 34.86 to 35.2, represented by 10 to 90 % probability off Paita.
Left and right Panels are the T–S diagram along Paita Line distinguished by periods: (a) during the weak EUCSCb (2000–2006) and (c) during the strong EUCSCb (2007–2014).

The boxes are the comparison between the water mass defined by Zuta, et al. (1970) with black line ([13° C to 15° C] [34.90 to 35.10]), and the red boxes are the proposed for the Northern Peruvian area in this study ([13° C to 19° C] [34.86 to 35.20]).
Results and Discussion

The yearly oxygen profile during May–June for the weak (a) and strong (b) EUCSCb periods.

(c) The average oxygen profile with its error bar (95% confidence interval) added is presented by periods, distinguished by colors blue and red for the weak and strong respectively.
Correlation coefficient between EUC velocity transport \([\text{m}^2\text{s}^{-1}]\) at (a) 0° N 170° W and (b) 0° N 110° W, with the 15° C isotherm depth off Paita, showing direct significant correlation coefficient at 10-months and 4-months lag respectively. Left and right axis are the R coefficient and p-values respectively. Red dashed line is p-value=0.05.

Consider that \(p<0.05\) (*) and \(p<0.01\) (**) are significant and highly significant respectively.
Conclusions

- Inter-annual modulations of the EUC is demonstrated using the data obtained by the long-term observations with TAO buoys along the equator from 2000 through 2015.

- During the period 2002-2014 it could be categorized in two periods regarding the EUC strengths. 1. A weak EUC, associated with the weaker pressure gradient force, from 2002 to 2006. 2. A more strong EUC period from 2007 to 2014.

- The water mass properties of the EUC seem to be modified through its subsurface stream, with relatively fresher and lighter water dominance in the downstream regions compared to the upstream.

- The peak occurrence of density is decreased from 26.5 to 26.1 while the EUC traverses from 147°E to 110°W. The similarity in the water properties found between off Northern Peruvian Coast and that in the downstream EUC along the equator 110°W, supports that the EUC feeds the EUC Southern Coastal branch (EUCSCb) off the Northern Peruvian Coast (Paita 5°S).
Conclusions

- Along Paita Line the 26 isopycnal deepens during the strong EUC period, whereas it was kept shallow in the weak EUC period. Similarly, the 15°C isotherm deepened during the strong EUC and shoaled during the weak EUC period.

- The water mass properties observed in the Paita Line: During a strong EUC period, water mass shows high saline and high oxygen concentration at the subsurface layers than during EUC weak period.

- Based on our results we propose a new definition of the EUC Southern Coastal branch water mass with the density range of $\sigma_\theta = 25.25 - 26.5$, salinity range between 34.86 to 35.20 and temperature from 13-14 to 18-19 °C.

- The Lagged correlation analyses show highly significant correlations between 15°C isotherm depths in the Paita Line and the EUC transport at 170°W and 110°W, with the 10-month and 4-month lags.

- Modulations in the EUC structure have a large impact on the local oceanographic and fishery resources off Peru.
Thank you for your attention...!
Acknowledgment

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As Researcher at the Faculty of Fisheries.
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As Researcher exchange student (2017-2018) in the Laboratory of Ocean Ecosystem Dynamics sponsored by the JASSO scholarship (Japanese Government).
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Results and Discussion

Left and right panels from (a) to (c) and (e) to (g) are the location, temperature and salinity of two Argo floats data during November 2014 to June 2015, located between 170° W–140° W and 140° W–110° W in the downstream region respectively.

White solid lines are the $\sigma_\theta = 24.5 - 26.5$ isopycnals each [0.5 kgm$^{-3}$].

(d) and (h) are the EUC zonal velocity at 0° N–170W and 0° N–140° W, while black contour lines are EUC Dynamic Range and the Core.