Ocean Science Discussions

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Reply on RC2

Gandy Maria Rosales Quintana et al.

Author comment on "Interannual variability in contributions of the Equatorial Undercurrent (EUC) to Peruvian upwelling source water" by Gandy Maria Rosales Quintana et al., Ocean Sci. Discuss., https://doi.org/10.5194/os-2021-13-AC3, 2021

Referee #2 : Anonymous

This study makes an attempt to link the interannual variability of the Equatorial Undercurrent (EUC) to that of the Peruvian upwelling, by back-tracking particles released in the Peruvian upwelling region to the equatorial Pacific. Particles tracking is an effective technique in tracing the origins of water masses. The application of the technique in this study, however, is insufficient. The authors estimated the contribution of the EUC to the Peruvian upwelling from just one release per year without demonstrating that this one release is representative of the oceanic condition of the corresponding year. For a fuller exploration of the connection between the EUC and the Peruvian upwelling, particles need to be released throughout of a year so that stable statistics can be obtained.

The analysis and interpretation of the results are also insufficient. Results from particle tracking show that strongest influence of the EUC to the Peruvian upwelling is in 1997 (an El Nino year). The author's explanation is flawed (e.g. flattening of thermocline, lines 201-203), or has no physical basis (e.g. lines 215-216). I suggest that the authors consider more carefully the timing of various events – the release time of particles, the transit time for particles to reach the equator, and the structure of the EUC near the eastern boundary at the time of particles' arrival so that a clearer view of particles dispersal can be obtained.

Response: Thank you for these suggestions, which are largely similar to those of Referee #2. As stated in previous response, extension of our trajectory analysis to include particles released throughout the seasonal cycle should address one concern, while a more careful explanation of how relative flattening of the EUC (during El Niño) can supply a greater fraction of upwelling water off Peru may convince the reviewer of this point.

Some Specific comments

Comment 1:

1. Introduction : Line 48: Are there available data for the total pelagic fish landings in 1997, 1998 and 1999

Response: Yes, there is available information on landings since 1980 up to now

from the Peruvian Sea Institute (IMARPE - http://www.imarpe.gob.pe/imarpe/index2.php?id_seccion=I0131020000000000000000) , although, data from 1980 to 1999 are only available as reports or published papers such the one we cited in our work (Ñiquen and Buchon 2004). From those sources, we established that more than 90% of the total pelagic landings in Peru is represented by the Peruvian Anchovy (also here in Bouchon Corrales M., 2018 doctoral thesis https://rua.ua.es/dspace/bitstream/10045/103709/1/tesis_marilu_bouchon_corrales.pdf And https://revistas.imarpe.gob.pe/index.php/boletin/article/view/171/161 - Spanish version only, although there are tables and figures easy to follow). That is why we used anchovy as the main pelagic species when explaining El Nino-EUC effects off Peru. We will add this last reference to our work. In case of 1999 landings: (http://biblioimarpe.imarpe.gob.pe/bitstream/123456789/1827/1/INF%20155.pdf Spanish version only)

Comment 2:

2. Methodology

Line 85 : Peruvian upwelling happens year-round with variability (your figure 3 and 4), what makes December 31 a good release time for particles to sample interannual variability?

Response: As for Reviewer 1 - According to previous studies (Espinoza-Morriberon et al, 2017, and our results) releasing particles in the Peruvian upwelling system, the seasonal cycle of the vertical mass flux (referred to as the upwelling) peaks from August to October and weakest from December to February, in accordance with the wind stress and nitrate flux. We considered December by association with El Niño. On reflection, and in response also to Reviewer 2, we will extend our trajectory analysis to include particles released throughout the seasonal cycle.

Comment 3:

3. Results and discussion

Line 172-173 : How did the authors determine from Fig. 8 that there was a flattening of the thermocline?

Response: We do not determine flattening of the thermocline directly from Fig. 8, where we use density on the y axis, rather refer to what is known. We will clarify the text accordingly. We will also plot temperature along the Equator in depth-longitude space (an additional figure), to make clearer this seasonal flattening.

Line 181-183 : These lines state that the EUC disappeared from the central Pacific in December 1997 – January 1998, and that the EUC transport anomalies exceeded -20Sv for much of 1997.

Response: We will moderate this statement to explain that the EUC was substantially weakened during the El Niño of 1997, most notably around November of that year (Johnson et al. 2000), consistent with highly negative transport anomalies in the NEMO-ORCA12 hindcast.

Lines 196-198: How do particles near 160W in the EUC arrive at the Peruvian upwelling region in 1997 in large numbers if the EUC transport is reduced or absent.

Response: As emphasized in the previous response, while the EUC weakens or is even briefly absent, it may extend further to the east during El Niño – consistent with flattening of the thermocline (so fewer particles upwell to the west). This would explain why more particles reach the eastern boundary via the EUC during El Niño, a point we will clarify in the revised manuscript. As for reviewer 1, we will provide further evidence for this explanation with analysis of year-round releases.

Line 200-203: Do the authors suggest that the EUC can persist when the thermocline (pycnocline) is flat?

Response: No, but we do not suggest that the thermocline is literally flat, rather flattened – see previous responses for elaboration on this issue.

Line 203-218: Perhaps this is an issue with timing instead of specific types of El Nino or La Nina. For example, the transport at 160W in late 1998 is unlikely making an impact on particles releases in the Peruvian upwelling region on 31 December 1998. The coastal flow and the EUC in the vicinity of the eastern boundary are much more relevant for the initial dispersal of particles.

Response: The negative transport anomaly actually persists for the second half of 1998 (Fig. 9b); given typical EUC velocity of 50 cm s-1, and the range of longitude (spanning 80°, or 8800 km), transit times range up to 204 days; on this basis, we will refer instead to EUC transport anomalies across the eastern equatorial Pacific during the second half of 1998.

Line 229: Was there a la Nina event in November 1993-March 1994? April-August 1998 was a transition period from El Nino to La Nina.

Response: Along the Peruvian Coast generally, after a strong EL Niño, occurs La Niña such as was observed after El Niño 1991 to summer 1993, and El Niño 1997 to June or July 1998.

Comment 4:

4. Conclusions

First sentence: The investigation is not systematic because only water that upwells in the Peruvian region in December each year is tracked. No evidence is provided that December is representative of the whole calendar year.

Response: We considered December by association with El Niño. On reflection, and in response also to Reviewer 1, we will extend our trajectory analysis to include particles released throughout the seasonal cycle.

Lines 285-286: The EUC is driven by zonal pressure gradient. When the thermocline (pycnocline to be precise) is flattened at a certain longitude, does the EUC not weaken or disappear at that location.

Response: As for Reviewer 1 - Flattening of the thermocline during El Niño of 1997-98, due to the weakening (or reverse) of the trade winds in the western and central Pacific region (McPhaden, 1999) is typical of the ENSO variability seen in historical model simulations (Terada et al., 2020) and observations (NOAA buoy array data) (Kessler & Mcphaden, 1995). We do not claim that the thermocline is completely flattened. Rather, it quasi-flattens, shallowing in the western basin and deepening in the eastern region – warming up the cold tongue

as observed in previous El Niños (Kessler & Mcphaden, 1995; McPhaden, 1999) for 1 to 3 months (observed in NOAA in situ data). Furthermore, we find that associated with flattening of the thermocline is eastward extension of the EUC, providing relatively more of the upwelling 'source waters' at the eastern boundary. We will clarify this point in the revised manuscript.