

Interactive comment on “Transition to El Niño conditions in the eastern tropical Pacific in October 2015” by Lothar Stramma et al.

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Transition to Observed El Niño conditions in the eastern tropical Pacific in October 2015

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Michael McPhaden (NOAA) had a look at the original OSD manuscript and mentioned that the title is confusing. Therefore we modified the title as marked above. He also proposed to give a brief opening paragraph about why it is important to study El Niño and as both reviewers especially reviewer 2 proposed to modify the introduction we introduced now an opening paragraph.

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Reviewer #1: Review of the paper “Transition to El Niño conditions in the eastern tropical Pacific in October 2015” by Stramma et al. This paper documents the changes in water masses and circulation patterns in the equatorial and eastern south Pacific from an oceanographic cruise which took place in October 2015 during El Niño (EN). Profiles and sections for temperature, salinity, oxygen, nutrients and ADCP current measurements are compared with those from previous cruises under different neutral, EN-like and La Niña-like conditions. The results show that the eastern flow associated to the EUC along the equator has greatly diminished in October 2015, and that temperature and oxygen have increased, while salinity has decreased. Near the Peru shore, cross-shore sections along the northern coast (9°S and 12°S) display typical EN conditions with the upwelling of warmer, more oxygenated waters, while the EN patterns are not evidenced at lower latitudes (14°S and 16°S). General comment: Documenting EN conditions in this region of the Pacific is important particularly as there are not many measurements published in the literature during previous events. I found the paper well written and interesting to read. Most of my comments are minor.

Answer to reviewer 1: We thank both reviewers for the helpful comments, which helped to improve the manuscript during the revision. We modified the manuscript as explained below in the detailed comments.

Reviewer #1: Minor comments: Abstract: L23: transition to EN conditions west of the coastal sections is not well documented in the paper. Figures are not shown and it should be discussed how EN can be present offshore and not nearshore. What is the local process that could compensate the nearshore warming? Wind-driven upwelling? This should be investigated and discussed in more detail.

Answer to reviewer 1: From our data we can't decode the processes responsible for the transition to EN west of the coastal stations. A possible explanation is the upwelling of left-over water from the pre El Niño period at the coastal station and the influence of the Peru Coastal Undercurrent which intensifies and shoals during El Niño at the stations west of the shelf station. Another explanation is that the observed transitional

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feature of normal conditions near-shore and El Niño conditions offshore is probably a consequence of the cross-shore pattern in vertical velocity during upwelling. The near-shore vertical velocity is to be expected substantially larger than the offshore vertical velocity (Fennel, 1999). A downwelling Kelvin wave could then neutralize the weak offshore upwelling and bring down the thermocline, while near-shore the strong upwelling would hardly weaken and for some time still bring up remnants of cold oxygen-poor water, until supplies feed from the offshore warmer and oxygen replete waters. The wind field would not need to change in order to produce this transition pattern in hydrography. These explanations are now described in the revised manuscript and the former Figure S7 is now included in the main text as Figure 11.

Reviewer #1: Introduction: P2L7: The denomination of Central EN or Modoki has been found in the literature previously to the publication of Dewitte et al., which is mainly a model study focused on the Peru region. I also think that other references (L10) should be cited to document the impact of EN off Chile (Ulloa et al., 2001 is an example but there must be others more recent)

Answer to reviewer 1: Reviewer 2 questioned to discuss the Modoki EN, as it is not investigated in our data set, nevertheless we like to mention its existence, but did not expand it to a longer discussion, we just added a reference to a Nature overview paper (Ashok and Yamagata, 2009). We added the proposed Ulloa et al. paper 2001 as an example for the influence of El Niño also on the Chilean region, however as the introduction should be shortened and we don't investigate the region off Chile and we did not expand this discussion further.

Reviewer #1: P2L19: 'Climate modelling evidence': I would rather ponder this statement and write that climate models suggest that a doubling in the occurrence..

Answer to reviewer 1: Text was rewritten as proposed using 'suggest' instead of 'evidence'.

Reviewer #1: P3L20: 'As a result of circulation changes' This is really vague.

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Could you be more specific?

Answer to reviewer 1: This text on circulation changes was a first information on El Niño related changes for the reference to Helly and Levin 2004. As the processes involved are described in more detail in the manuscript, 'as a result of circulation changes' was removed here.

Reviewer #1: P6L19: 'The equatorial spreading of the thermocline' This spreading of the thermocline is unclear to me. Is it zonal, meridional? Could you rephrase?

Answer to reviewer 1: This is meridional spreading and now 'meridional' is included and the reference to Johnson et al. 2002 was included.

Reviewer #1: P6L25: '...intensifies from 16 to 15.' is such a decrease of the mean oxygen concentration robust? This 1 micromole difference seems very small.

Answer to reviewer 1: Right, this change in oxygen of the ODZ core listed by Paulmier and Ruiz-Pino is removed from the text.

Reviewer #1: P7L10: The sentence is clumsy. I also do not understand the concluding sentence of the paragraph. Why should higher salinities be expected in the pycnocline during EN?

Answer to reviewer 1: This part was rewritten, removing the information on the late El Niño phase, which is not investigated in our manuscript. Instead the reason for the higher salinity in the pycnocline due to northward progression of the salinity maximum of the South Pacific Tropical Water under the modified current bands during El Niño is explained.

Reviewer #1: P8L6: What about local increase of precipitation and/or poleward displacement of the equatorial front (associated with the ITCZ) which separates fresh waters off Ecuador from more saline waters off Peru?

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Answer to reviewer 1: Right, the higher precipitation will be the major contribution and is now mentioned before the equatorial upwelling. Some literature shows a very minor shift of the ITCZ in this region (e.g. Chen and Lin 2005, Monthly Weather Review), hence we did not mention it here.

Reviewer #1: P8L21: higher PNM during EN. I understand the deepening of the peak due to the deeper pycnocline but not the more intense PNM. How can it be explained? could this be due to an increase in denitrification?

Answer to reviewer 1: The higher nitrite concentrations in the PNM during EN are most probably resulting from (i) high nitrite conc. in the PNM of the SPTW which have been transported towards the equator and (ii) higher ammonium oxidation rates due to a reduced photo inhibition at deeper water depths during EN. Denitrification only occurs at suboxic/anoxic conditions. Therefore, the occurrence of denitrification is very unlikely because of the relatively high ambient O₂ concentrations. We modified the text accordingly.

Reviewer #1: P9L6: A citation of EN years considered in Czeschel et al. 2012 would be useful here.

Answer to reviewer 1: The measurements are from the El Nino years 1982/83 and this information is now mentioned in the text.

Reviewer #1: P9L16: I would rather say an 'ocean model' than a climate model which refers more often to ocean-atmosphere coupled models.

Answer to reviewer 1: In the title of the Cravatte et al. paper it is called 'climate model' and in the abstract it is named 'climate-type OGCM', but nevertheless we changed it to 'ocean model' to avoid misunderstanding.

Reviewer #1: P10L2: 'nin Nov 1982' is repeated twice in the sentences

Answer to reviewer 1: The first reference to November 1982 in this sentence was removed.

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Reviewer #1: P10L11: in Fig 6, could you add 'positive eastward' for zonal velocities?

Answer to reviewer 1: We added the velocity flow direction of both components as well as the date of measurements to the figure caption.

Reviewer #1: P11L18: 'November minimum at 95_W'. A reference is missing here and I do not see how this statement on the EUC at 95_W backs up the fact that it should be a reasonable estimate of the EUC in neutral EN conditions.

Answer to reviewer 1: This transport refers to a reference by Johnson et al. 2002, which was listed earlier in the manuscript. This reference is now included also here.

Reviewer #1: P12L5: the reference to Gutierrez et al. is misplaced. This sentence should be moved to L1 where SST are described. I am not sure Sydeman et al is really relevant here.

Answer to reviewer 1: The sentence was moved to the beginning of the paragraph where the SST is described as proposed. The reference to Sydeman was removed.

Reviewer #1: P12L16: I do not have a problem with citing Strub et al which is a review, but other papers should be cited as well (Halpern et al. 2001, Enfield, 1981; Huyer et al., 1987)

Answer to reviewer 1: For this text part Halpern 2002, Enfield 1981 and Huyer et al., 1987 were included.

Reviewer #1: P12L20: Here same remark as before, I think that Strub et al 1998 can be cited but other papers as well (which are cited by Strub in his review).

Answer to reviewer 1: Again, for this text part Halpern 2002, Enfield 1981 and Huyer et al., 1987 were included.

Reviewer #1: P12L26: 'Reduction of the ODZ area': I do not understand how this area is computed. It seems more a vertical displacement of the OMZ than a re-

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duction of its area. Could you clarify?

Answer to reviewer 1: The ODZ was defined for dissolved oxygen < 0.5 ml/l and the area considered 6°-20°S. According to the paper by Helly and Levin (2004) there could be a vertical displacement with a depression by 100 m and the area could be reduced from 77,000 to 30,000 km². This information is now added.

Reviewer #1: P13-16: I think there are too many figures in the supplementary here. Please reduce them and add some of them to the paper section, as it is very difficult to follow without looking at the figures in the supplementary.

Answer to reviewer 1: We moved the supplementary figures S1 and S7 to the main text as they are important to understand the observations. The other supplementary figures are of interest for readers with specific detailed interest and we left them in the supplement.

Reviewer #1: P14L3: could the lower nutrient concentrations in october 2015 be due to the seasonal variations of the nutricline?

Answer to reviewer 1: We do not see any evidence to attribute this decrease in nutrient concentrations to normal seasonal variations. For example, the recent discussion paper by Graco et al. (<http://www.biogeosciences-discuss.net/bg-2015-567/bg-2015-567.pdf>) shows a nutrient concentration time series from 1996 to 2010. The differences between October and December are small for most of the years presented and for all nutrients measurements. Unfortunately, the time series presented does not include either year presented in our manuscript, but we conclude that there is no distinct pattern between October and December since 1996.

Reviewer #1: P14L14: I would conclude this sentence by saying explicitly that this process may produce more nitrate. I think that is important as one may think that all nutrient pools (phosphate, silicate AND nitrate) decrease during EN, which is not always the case from your observations.

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Answer to reviewer 1: We have now wrapped up the sentence by clearly pointing out that complete nitrification will result in more nitrate.

Reviewer #1: P14L24: You suggest that diatom biomass may increase during EN due to the N:P increase. However both nitrate and phosphate concentration reduce strongly during EN, which should impact negatively phytoplankton growth more than the N:P increase. Previous studies have shown that the surface chlorophyll observed from satellite decreases during EN (Carr et al. 2002) and the ecosystem suffers dramatic changes during extreme EN (Barber and Chavez, 1983, Chavez et al. 2003).

Answer to reviewer 1: In this section we were comparing data from 2012 with data from 2015 (now Fig. 11). While the reviewer is correct that a reduction in both nitrate and phosphate could negatively impact phytoplankton growth even if the N:P ratio was higher, we did not see a decrease in nitrate during our October 2015 cruise. Instead, we found that both nitrate and N:P was higher, which, as we suggest, could increase phytoplankton biomass.

Reviewer #1: P15L7: At 12_S, higher nitrate... how can higher nitrate indicate a developing EN? This sounds contradictory.

Answer to reviewer 1: As previously outlined, higher oxygen concentrations during El Nino would result in less denitrification and more complete nitrification, which in turn would result in more nitrate. We have now added text to the end of this section to make this more clear.

Reviewer #1: P16L14: I think you should also mention the strong intraseasonal signals in the equatorial pacific in neutral periods, with the passage of upwelling and downwelling waves at intraseasonal time scales (Cravatte et al., 2003; Echevin et al. 2013). during a cruise, if sampling is performed during the passage of a downwelling wave in a neutral EN period, this might have some similarity with EN conditions.

Answer to reviewer 1: The influence of intraseasonal signals is now mentioned and the

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references Cravatte et al. 2003 and Echevin et al. 2014 are included.

Reviewer #1: P17L15: I do not understand the sentence. Please rephrase.

Answer to reviewer 1: This sentence was rewritten separating the equatorial observations and the observations off the South American continent.

Reviewer #1: P17L18: Measurements are carried out by CNRS, IRD and IMARPE . IFREMER is the owner of the glider, which is part of the french national glider pool. Here is a link with more precise information (in french): <https://www.ird.fr/toutel-actualite/actualites/communiqués-et-dossiers-de-presse/cp-2015/lancement-de-cienperu-projet-cienperu-projet-d-etude-des-impacts-d-el-nino-2015-2016-sur-l-ecosysteme-marindu-perou>

Answer to reviewer 1: The text was modified according to your information on the groups carrying out the measurements and the web-link was replaced.

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