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Ocean Science Discussions

Interactive comment on "Joint effect of the western and eastern Pacific warm pools on ENSO cycle" *by* Q. Qi et al.

Q. Qi et al.

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First of all, we would like to thank Dr. David Webb for his helpful comments and for his appreciation to our endeavor for the ENSO research. In the following we address our answers to Dr. Webb's comments:

Comment 1: The paper is concerned with the analysis of data from the Paciﬁc covering the period 1950 to 2007. Gridded data of sea surface temperatures and 850 hPa winds are used to determine the eastern edge of the West Pacific Warm Pool, the southern edge of the East Pacific Warm Pool and their connections with the El Nino (NINO3 index) and the winds over the western, central and eastern Pacific.

Author: ENSO is one of the most important interannual climate signals involving the air-sea interaction, and essentially it is associated with the redistribution of mass and

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heat in the Pacific upper ocean. Warm pools assemble the warmest seawater in the world with a vast territory and abundant heat content, which hold the balance in the Pacific air-sea coupling system. Aims of our article are to analyze the WPWP zonal displacement and the EPWP meridional displacement and their relations with zonal and meridional winds, to discuss their effect on ENSO, and to propose a new idea that the two warm pools jointly effect on ENSO.

Comment 2: I have a number of areas of concern: 1. The paper uses very long datasets and makes a number of points about the changes in climatology over this period. However the sources of data will have changed and this is not referred to. As an example, the early ocean data is probably based primarily on bathythermograph records and the sea water inlet temperatures measured by ships engine rooms -often made at the depth of a few metres. Much of this data will only have been available along the main sea routes. In the Pacific there may have been large areas each year without good data. Later XBT and satellite temperatures will have been added, satellites measuring temperatures in the top layer of ocean and doing so to the same accuracy over much larger areas of the ocean. Similar changes will also be found in the data used to determine the atmospheric fields. Thus before discussing climatological changes the authors need to convince the reader that the effect of changes in measurement techniques and sampling has been allowed for and that they will not affect the results.

Author: The SST and wind data are delivered from the National Climatic Data Center and the National Centers for Environmental Prediction’s Reconstruction and Reanalysis Datasets. Those data are presently considered as more reliable data available for the climate change study (please see: Simth et al, 2003, 2004; Kistler et al, 2001 for details). Therefore, results from analyzing these data are comparatively reliable. We agree that the climatology points in our manuscript should be verified by using other reliable and complete data. However, Due to the concurrent lack of observation and the quality concern impacted by observation system and sampling, we cannot wait until the observations having been into perfection and maturity.

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Comment 3: In many places the paper seems to assume that that the expansion and contraction of the warm pools implies movement of water. For example in the abstract (page 164, line 8) "the eastward extension of the WPWP .... can supply ... warm water into the NINO 3 region". In section 2.2 (page 169, line 8) "The WPWP and EPWP are two warm water engines." and "... the WPWP and EPWP shift ... . As a result ... warm water flows into the eastern equatorial Pacific and warms up the seawater...". However all that one can be sure of is that the region has warmed up. This is because of the Ekman induced divergence at the equator in the eastern Pacific (caused by easterly winds at the equator) and the westward ﬂowing surface currents in the same region. Surface temperatures in the east are cold because of the upwelling. Heating from solar radiation and the atmosphere warms the water as it moves west or away from the equator. If the winds drop, as during an El Nino, temperature can rise because there is less upwelled water and the surface current is reduced. However the surface currents are still on average towards the west and away from the equator.

Author: Warm pools are the pileup of the warmest Pacific seawater. We defined the warm pool as warm water mass that its movement is characterized by displacement of the 28C; isotherm. ENSO is internationally denoted by the SSTAs in Nino3 region, as a result, studying the factors that impact the SSTAs in Nino3 region and where the high-temperature water in Nino3 region comes from are very important. There were several proposed theories on the causes of formation of ENSO: some believe that the occurrence of El Nino is related to the weakness of upwelling of cold water in the eastern Pacific (as addressed by the referee), some insist on the important effect of the WPWP's eastern-ward expansion (Wyrtki, 1975; Picaut et al, 1996; etc.), and some persist that the southern-ward extending of the EPWP warm water plays an important role in the El Nino formation (Xiu, 1991; Zhang et al, 2006). From the point of oceanographic view, the inflow of warm water is crucial to the warming process in the eastern Pacific. The authors agree completely with the referee's point for the important effect of local variations on anomalous variation of SST in eastern Pacific. However, here the effect of displacements of warm pools on the formation and evolution of ENSO

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is stressed. The relaxation and ceasing of trade wind is in favor of the eastward flowing of the WPWP and the southward flowing of the EPWP into the Nino3 region. As a result warm water increases there making the sea level and the temperature rise rapidly. As to the variation of ocean currents, the averaged current is westwards in most El Nino years. But in the equatorial, the SEC is weak, and the NECC becomes strong (Wang et al, 1987) during the El Nino, which causes the equatorial eastward current anomaly that transports the warm pool water into the eastern Pacific (Zhang et al, 2001), making the sea level and the temperature raise rapidly. This can be taken the 1997/98 El Nino for instance.

Comment 4: The paper also appears to confuse correlation with cause and effect. Thus in section 3.1 (page 171, line 16) having shown that there is are correlations between the wind and NINO 3 temperatures the paper these correlations "suggest that the zonal displacement of the WPWP was mainly forced by the wind anomaly". This is then followed by similar statements. My point is that the correlations may support theories of how an El Nino develops but they do not prove the theories or prove new causes and effects.

Author: It needs to point out that there are lots of studies indicating the important effect of equatorial zonal wind anomaly on ENSO. So in our manuscript, this issue is out of our discussion. Only the zonal displacement of the WPWP and its relation with the western and central zonal wind anomaly was analyzed. Our analysis is based on the important fact that: warm pools assemble the warmest and widest seawater that holds the balance in the Pacific air-sea coupling system. Their movements not only impact the redistribution of the mass and heat of the seawater, but also the anomalous variation of wind associated with the air-sea interaction process. ENSO is the process of redistribution of the mass and heat in the upper tropical Pacific Ocean. The warm pools have important effect on ENSO because of their important roles in the air-sea interaction system. We can say that the interannual movements of warm pools are one of the important primarily attributes of ENSO (Machphden et al, 1998; Picaut et

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al, 1996; Delcroix, 1998, 2000; Maes et al, 2004; Zhang et al, 2004). So studying the movement of the warm pools is very significant to the theories and prediction of ENSO.

Comment 5: I am also concerned why the paper includes a correlation with the meridional wind in the ’Northeastern Pacific’ region without also including the zonal wind. Was this an oversight? At the equator a correlation of a zonal wind with a zonal current is reasonable, because the effect of the Earth’s rotation is small in the equatorial wave guide. In the east a correlation of the zonal winds near say 10 N might be considered physically reasonable, because the zonal wind will drive a northward Ekman current that will affect the position of the 28 degree isotherm. However a correlation with the meridional wind in the same area seems physically less likely -unless say it is involved in the upwelling in the Gulf of Panama. A related point is the question of whether the average wind in the region is in any way independent of the wind at the equator. It is possible that essentially the same correlations would be obtained with winds at the equator. As the zonal wind here is responsible for equatorial upwelling, it is likely to have much more physical significance in understanding the overall El Nino problem.

Author: Previous studies suggested that the zonal wind has important effect on ENSO whereas overlooking the meridional wind. So, in our manuscript, we discussed the corresponding correlation between the EPWP meridional movement and the meridional wind anomaly over it without involving the zonal wind and the effect of the wind anomaly on ENSO. However it should be point out that, our analysis shows that the zonal wind anomaly lags the EPWP meridional movement by around one month. Due to the important effect of the EPWP meridional movement impacted by meridional wind anomaly over it on ENSO, it suggests that the effect of the meridional wind on ENSO (which can also be informed from the southward displacement of ITCZ during El Ninos) should not be overlooked.

Comment 6: My final main area of concern is where this is all leading us. The authors try and make the point (page 169, line 20) that in at least one case (1976) an El Nino

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appeared to be triggered primarily by an expansion of the East Pacific Warm Pool - although the case they make is not well argued partly because of the poor resolution figures (see below). If this is correct then it is a really important point. The trouble is that in most cases, the expansion of the warm pools and the increased temperatures in the NINO3 region could all result from some general increase in temperature due to some, possibly re-mote, cause. As a result one should expect the correlations between measurements to be high anyway. If some separate factor involving the East Pacific Warm Pool is important, then the best one might do within the statistical analysis is to show that a model (like Eqn.1), which takes into account data from both warm pools, gives a much better ﬁt to the NINO 3 data than a model only involving one of the pools -after allowing to the extra degrees of freedom in the joint model. For linear models a statistical F test can be used to make this check. Although the above comments are critical, I appreciate that the El Nino is still not fully understood and research still needs to be done on the different factors and mechanisms involved. The present paper tries to do this in a new approach making use of some long data sets from the region, and for that reason is to be commended. However the above points still need to be addressed before the paper proceeds further.

Author: We consider that, other than solar radiation, the warming in eastern Pacific is also related to the increase of warm water. So the emphasis of our research is on the joint effect of the WPWP zonal movement and the EPWP meridional movement on ENSO. This is also a new attempt to investigate the cause of ENSO. Employing the linear regress method, we obtain the optimal regress model available between the two warm pools and the Nino3 SSTAs checking with F test. It yields that the joint effect of the two warm pools on ENSO should not be overlooked.

Comment 7: Fig. 1 and 2: The discussion of these figures could do with a NINO 3 graph using the same horizontal scale. The mean position of the edges should be given in the caption or on the figure. The horizontal scale is too cramped for provide any information concerning delays of a few months. A comparison of Fig. 1 and Fig.

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4b (page 171, line 3) is impractical. There is a similar problem with the discussion of the 1976 events (page 169, line 20) but here a separate set of plots could be provided.

Author: Good suggestion! The Nino3 graph can be added, and the averaged position of the edges will be mentioned in the text. The information concerning time lag was not based on simply comparison of the figures but time lag correlation analysis. We will modify the inappropriate expression. Ok, the separate set of plots concerning the 1976 events can be provided.

Comment 8: The figures state that these are 5 month running means of the data - so does each point represent the mean of the previous five months or is the filter centred about each data point? I did not find any similar statement in the text. Did the correlation analysis use 5 month running means? -in which case could apparent delays of a month or so be artifacts of the filtering scheme?

Author: Five month running means the filter centred about each data. Whereas the correlation analysis was done without the data treated with 5 month running mean.

Comment 9: Fig 3. It would help if the paper also showed the position of the warm pool and wind anomaly regions used in the analysis as well as the NINO 3 region. This figure also shows degrees east at all longitudes -whereas in the text the north-east Pacific wind region is 90 to 120 W. (Incidentally, most oceanographers consider the NE Pacific to lie north of 40 N. The paper needs another term for the eastern wind analysis region).

Author: The figure will be confused if the three wind regions were drawn in the same figure. For better performance, we don’t think it is better to give the wind regions. We agree with the referee that the term NE Pacific is changed to tropical NE Pacific.

Finally, we would say that this manuscript focuses on the correlation between the two warm pools and the Nino3 index. As to the correlation between the movements of

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warm pools and wind, currents, thermocline, sea level, and solar radiation etc., it will be addressed in another manuscript.

Interactive comment on Ocean Sci. Discuss., 5, 163, 2008.