Anonymous Referee #3

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This manuscript is long and extremely hard to follow. From what i can gather there is no new results presented until 11 pages into the manuscript. Given that there are only 6 pages discussing the results, an 11 page introduction is clearly too long. In this introductory material, there is a lot of discussion of the authors previous results, some relevant and some not so much along with a lot of literature that is not really relevant to the current study. Further to this, and probably directly related, this extremely long introductory section is very hard to follow with no clear logical flow. There are also places where it seems, it may simply be the incorrect usage of grammar, that author may not totally understand the current status of our understanding of ENSO. There are also times, however, where the author appears to have a good grasp on the literature.

1. The volume of Inroduction is decreased and section 2 is deleted.

From what I understand of the authors previous work, it suggests that the Southern Ocean can influence the tropical Pacific. An interesting hypothesis. However, the question of whether these tropical Pacific changes are big enough to affect ENSO is not addressed here or in the previous work. The Nino 4 temp anomalies presented in Figure 2 are scaled, by how much is not mentioned. Are they tiny? Given that three recent westerly wind bursts on the equator have generated subsurface temperature anomalies that are up to 6oC, the subsurface temperature changes shown in Figure 3 are very small (+/- 0.5oC). Thus, it is not clear whether these anomalies would even impact the energetic tropical Pacific ocean-atmosphere system.

2. The scaling value of NINO4 in Fig.2 (1.6^{o}C) is irrelevant here since the figure shows similar variability of different parameters. The absolute values of NINO4 index (I would like to remind that it is SURFACE temperature anomaly), which reflects joint effect of the interaction between the ocean and atmosphere in the tropics and influence of the Southern ocean, really can achieve up almost 6^{o}C. However, Fig. 3 shows the zonal model SUBSURFACE temperature difference (~1°C) in the tropical Pacific, which characterizes the tropical thermocline slope. Therefore difference between NINO3.4 and NINO4 indexes, rather than the absolute values themselves, is more relevant for the comparison with the model. The maximal absolute difference between NINO3.4 and NINO4 anomalies for 1950-2011 is about 2^{o}C, so our model difference (~1°C) is in a good agreement with observation since the following development of surface and subsurface anomalies due to the interaction between atmosphere and the ocean is not taken into account in our numerical experiments.

This issue was discussed in the previous version of the paper:

Since after the appearance of temperature anomalies in the tropics the subsequent interaction between the atmosphere and ocean in the model tropics was excluded (due to fixing temperature and salinity fields at the ocean surface in these numerical experiments, which corresponded to values averaged from June to August over a whole modelled 20-years period (from 1984-2003 HadCM3 model output)), the development of surface and subsurface (within Ekman layer) anomalies was excluded, nevertheless the zonal model temperature difference (~1°C) in the tropical Pacific (which characterizes the thermocline slope here) is comparable with observation.

This work focuses on trying to link ENSO with SLP west of the Drake Passage. This link appears tenuous and the one plot that shows SLP in the region plotted against Nino3.4 SSTA, shows that SLP appears to lag Nino3.4 in many cases. Regarding the increased role of these SLP changes on ENSO since 2000, the correlation between the two indices is actually lower for this period than for the period prior to the 2000s.

3. The lags in Fig. 6, which referee can see at the end/beginning of years, are really the cases when NINO3.4 lags SLP about 2-3 months (since SLP curve is shifted 4 months forward). The cases when NINO variability is in phase with/or slightly leads SLP ones are seen only in the middle of years (these events are not considered by the paper), while at the end/beginning of years (when the maximal developments of ENSO occur) SLP variability always leads NINO3.4 (exactly these cases are considered by the paper, i.e. we look at SLP change several months before maximal ENSO development). As was stated in the text the stochastic processes, which always occur during the interaction between the atmosphere and the ocean, led to that time lags between the two indices are in a wide range of 3-5 months.

Though the correlation between the two indices is slightly lower after 2000, but tests to determine the significance of difference in correlations between two periods shows that this difference is not statistically significant. A slightly higher value between the two indices prior to the 2000s can be explained by generally colder conditions before 2000s that corresponds to higher positive value of the skewnesses of PC2 and PC5 (see the text). Hence more likely that before 2000s over the region upstream/near of Drake Passage high atmospheric pressure was settled, and hence more warm ENSOs than cold ones developed (see also the text). These SLP anomalies, according to the values of PC2 and PC5, are generally bigger and prolonged before 2000 than after (the same is true for NINO-index), therefore corresponding correlations slightly bigger for this period. See also p13, L313-318 of a new version of the paper.

Again this does not appear to support the authors conclusions. The EOF analysis used further decomposes these pressure signals, and the fact that the 5th EOF which accounts for 5% of the variability is being discussed does not add value and even highlights how tenuous this link is.

4. The reviewer's criticism using the 5-th EOF for the analysis likely can be due to by the paper by Overland and Preisendorfer (1982) who showed that for their analysis only the first four PCs were significant. However, as follows from Overland and Preisendorfer (1982), the significance of EOF modes depends on both length of observation data set and the choice of a number of eigenvalue statistics. Therefore a significance of our 5-th EOF mode has been checked: Monte Carlo test has been done similar to Overland and Preisendorfer (1982), but the results of the test have not been presented in the early submitted manuscript. Now the result of this test showing statistical significance of EOF5 mode is added in this new version of the paper. Statistically significant correlation between PC5 and NINO index only after 2002 means that the EOF5 mode, describing the variability of the strength of meridional shear of zonal wind to the west of Drake Passage, and characterizing air jet instability over this region, became to be a significant contributor to the development of maximal phase of the ENSO after 2002 with lead time of about 8 months. It is worth noting that though EOF5 mode explains only 5% of the total SLP variability (that is in agreement with "probability distribution tail" that can describe

such extreme events as ENSO), but the pressure difference between centres of regions with high and low pressure of EOF5 mode (Fig. 8c, now Fig.6c) is more than 50% of a similar difference of EOF1 mode (Fig.8a, now Fig.6a). Hence the variability due to EOF5 mode can be significant factor leading to the formation of SLP patterns shown in Fig.5 (now Fig.3).

In my opinion, if the author really wants to identify the affect these Drake passage (or EOF5) winds can have, I suggest using partially coupled CGCM simulations. These simulations could be coupled in the tropical Pacific, thus ensure they have ENSO variability, while forcing with some form of idealised forcing in the Drake Passage region.

5. Of course, it would be very useful to prove the main idea of the paper using this approach (it is a task for future study). However such modelling is expensive enough and therefore this "cheaper" evidence can be base for further more expensive studies.

Major comments

page 946: Oscillator model paradigm for ENSO are now widely accepted, which is generally true. However, three different Oscillator models are presented and the differences between these oscillator models is not described and the explicit mentioning of Kelvin waves makes me think that maybe the author does not understand the recharge oscillator.

Following this, it is also mentioned that Kelvin waves may initiate events. This is pretty widely accepted, and relates to the role of westerly wind bursts triggering events.

page 947: My understanding of the propagation of SSTs during ENSO events, is that all La Nina and most small-moderate magnitude El Nino events propagate from east to west (e.g., see McPaden and Zhang 2009). The two big El Nino events of 1982/93 and 1997/98 are those which propagate from west to east. Interestingly, and in direct contrast to what you are stating here, these two events are widely considered conventional and they have there maximum SST anomalies in the nino 3 regions.

The lead lag relationship between nino 3 and nino4 region SSTA is simply indicative of SSTA propagation, so i would expect this lead-lag relation to reverse if the big El Nino events of 1982/83 and 1997/98 could be removed from this analysis.

page 953: it is mentioned that two different equatorial Kelvin waves are triggered by the Southern Ocean forcing, one at the western boundary and one of the opposite sign in the central Pacific. Is this consistent with the wave mechanism reported? Given it fundamental role in the hypothesis presented here, these waves and there pathways really needs to be better described. There are many other components of this introduction which can be removed to facilitate this, in my opinion, so the length need not be increased. Infact, really think the intro needs to be shortened significantly.

6. The misunderstanding is due to the fact that author tried to minimise the volume of previous paper. Now the introduction and section have been completely revised to avoid the above misunderstanding.

Page 955, how can a high atmospheric pressure located upstrean of the Drake passage "lock" the Drake Passage?

7. The text was modified:

As we saw before the region upstream of Drake Passage is important from the point of view of a balance between the wind stress and form stress in Drake Passage that impacts the variability of the meridional mass fluxes in the Pacific sector of the Southern Ocean. Therefore it is clear that a high atmospheric pressure settled over the upstream of Drake Passage region changes the above balance in Drake Passage, and together with the inverse barometer response to atmospheric pressure result in equatorward meridional flux anomaly in the Pacific sector of the Southern Ocean …

Bottom of page 955. Figure 5 does not confirm this hypothesis. Only two events are shown, why not show this pressure pattern for all El Nino and La Nina events? Even then, if all of these composite members display the upstream Drake passage pressure signal (as well as the composite mean) it does not imply cause. It is suggestive of a relationship but could be an affect, or even simply luck...

8. Four events are shown indeed (2 for warm and 2 for cold events). Similar distribution of SLP anomalies has also been observed 3-5 months before the development of maximal phase of the ENSO in 1992, 1994, 1995, 2000, 2002, 2004, 2006, 2007, 2008, 2009 and 2010 (see text).

However the increase of number figures for Fig.5 is not advisable, therefore the proper figures are shown only here (Figs 1 and 2). EOF analysis shows later that EOF2 explains this mode leading ENSO 4 months, i.e. it (together with correlation between Δp and NINO, see text) means that the upstream Drake Passage pressure signal does imply cause.

First paragraph, page 956: The last sentence suggests that the pressure anomalies in the upstream Drake passage region is the cause for all observed ENSO events since the 1990s. If this is true, shouldnt an index of pressure in this upstream region show a strong correlation with ENSO if this is the case? This would be much easier way to present this idea.

9. Again, as was stated in the text the stochastic processes, which always occur during the interaction between the atmosphere and the ocean, led to that time lags between the two indices are in a wide range of 3-5 months, and as seen from Fig.5 (now Fig.3), the locations of SLP anomalies upstream Drake Passage are not the same for different periods. And the main reason, that analysis of SLP anomalies upstream Drake Passage is useless, is that this region is characterized by high atmospheric cyclonic/anticyclonic variability minimizing values of any SLP anomalies here. Therefore the lag correlation analysis between an index of pressure in this upstream region and ENSO cannot prove this idea, but the variability of atmospheric pressure at 280E, 35-45 S, which position is chosen according to the preferred propagation away from the Southern Hemisphere subtropical jet waveguides indicated by Ambrizzi et al., 1995, is more favourable for the presentation. See also comment 3.

Second paragraph, page 956: You spend the whole page trying to say that the pressure signals upstream of the Drake Passage precede El Nino events, then in this paragraph you say this same region is crucial for the dynamics of the whole ACC. How did this huge leap come about? No analysis of the ACC has been presented that i can see.

10. The text was modified:

Now when we realise that the atmospheric conditions over the region upstream of Drake Passage can be significant for ENSO development, we can choose some other index.

Third paragraph, page 956: There is no evidence presented for defining this line at 48oS. It is stated that it separates cyclones and anticyclones, but some evidence of this is needed.

11. The statement was based on results by Stepanov, 2009a (visualisation of SLP anomalies clearly shows this). To avoid some additional not relevant questions the text was modified.

Figure 6: The pressure index has been shifted forward by 4-months (caption) but it appears to lag N34 SSTA in many instances. From my understanding of the mechanism, this shifted index should line up the peaks. This fact makes me think that an affect of ENSO is being identified, not a cause.

12. The lags in Fig. 6, which referee can see (about 1-2 months) at the end/beginning of years, are really the cases when NINO3.4 lags SLP about 2-3 months (since SLP curve is shifted 4 months forward). The cases when NINO variability is in phase with/or slightly leads SLP ones are seen only in the middle of years (these events are not considered by the paper), while at the end/beginning of years (when the maximal developments of ENSO occur) SLP variability always leads NINO3.4 (exactly these cases are considered by the paper, i.e. we look at SLP change several months before maximal ENSO development). As was stated in the text the stochastic processes, which always occur during the interaction between the atmosphere and the ocean, led to that time lags between the two indices are in a wide range of 3-5 months. The text was modified for clarity.

page 958: How is the affect of tropical cyclones excluded?

13. I meant that we are not considering the effect of the tropical cyclones here. The text was modified:

Since the mid 1990s the SST became warmer, therefore if we exclude from consideration the effect of the tropical cyclones (they rarely form within 5° of the equator (Henderson-Sellers et al, 1998) and their impact is significant in the northwest Pacific Ocean basin only), it is reasonable to suppose ...

Hasn't the standard deviation of Nino3 or Nino3.4 SSTA also decreased since the 2000s consistent with this decrease in SLP variability? Given that it is a tightly coupled system, what role does this SST standard deviation decrease play in the decrease in tropical pacific SLP variability?

Are these changes in SLP variability significant? A Montecarlo test, or something similar, should be carried out to see whether any 10yr (or even 4yr as in Fig. 7f) period in the pre-2000 data displays changes in SLP variability that are as big as the highlighted post-2000 (or post 2008) period.

The investigation of atmospheric pressure variability in the tropics can be special issue for further study. The aim of the paper is demonstration of a link between processes in the Southern Ocean and ENSO rather detailed study of processes in the tropics. However, the referee is right, it is worth to note about correlation between NINO index and SLP variability. However, again, we should estimate the variability of the difference, e.g. between NINO3.4 and NINO4 indexes, rather than the change of absolute values themselves since the zonal gradient is significant for the intensity of Walker circulation, which can be characterized by SOI index. Analysis shows that really standard deviation of the difference between NINO3.4 and NINO4 for 1989-1999 period 2 times more than for 2000-2011. Besides, there is a significant correlation of the difference between NINO3.4 and NINO4 with SOI for 1989-1999 (-0.51), while the same correlation for 2000-2011 is about zero. Thus, the significant correlation before 2000 and zero ones after 2000 says that the contribution of atmospheric component of ENSO due to the variability of atmospheric forcing in the western equatorial Pacific reduced, and hence the variability over the Southern ocean recently can contribute more in the processes of ENSO developments than it was before the 2000s.

It is worth noting also that the significant correlations between SOI and NINO3.4 (-0.84) and NINO4 (-0.79) for 2008-2011 period are higher than during 2000-2007 (-0.58 and -0.47, respectively for NINO3.4 and NINO4). The differences in correlations between two periods are statistically significant. The change of the above correlations is in agreement with results presented in Fig. 7 e-f (Fig. 5 e-f now). The text was modified.

regarding: SLP variability in the Drake Passage region hasnt changed. Looking at Figure 7a and b, i would say that the variability of the tropical Pacific had not changed significantly either. What happens if you extend c and d so that you can see the southern ocean.

The proper figures are shown here in Fig.3.

Minor comments:

page 946: "Under these conditions" sentence is repeated.

The text was modified.

Figure 2: why plot the transport of the drake passage, it apparently has no relationship

with the other two time series. What is the magnitude of

The figure was removed.

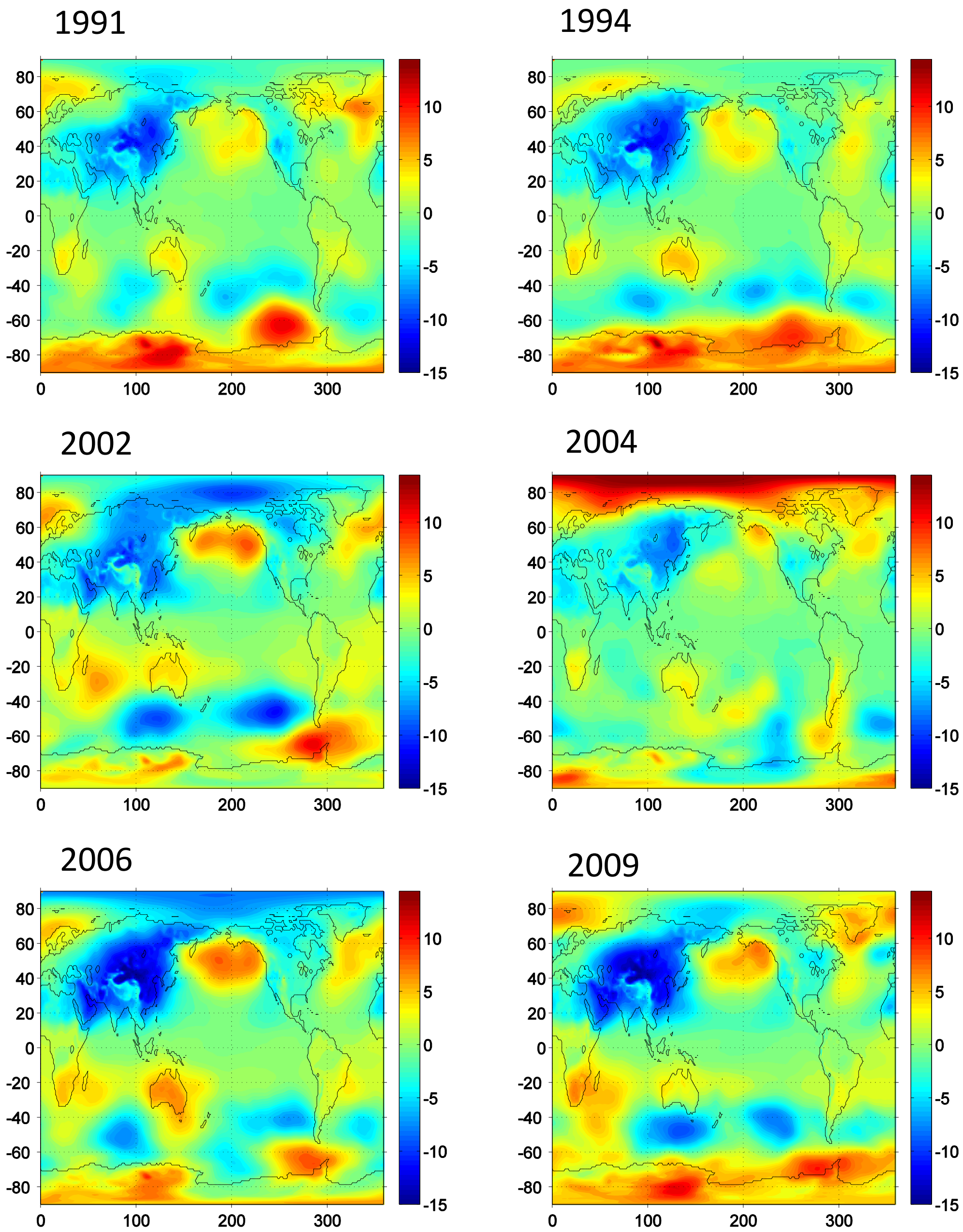

Fig. 1. 2-3 month mean sea level pressure anomaly (in HPa) observed 3-4 months before the maximum phase of the development of warm ENSO.

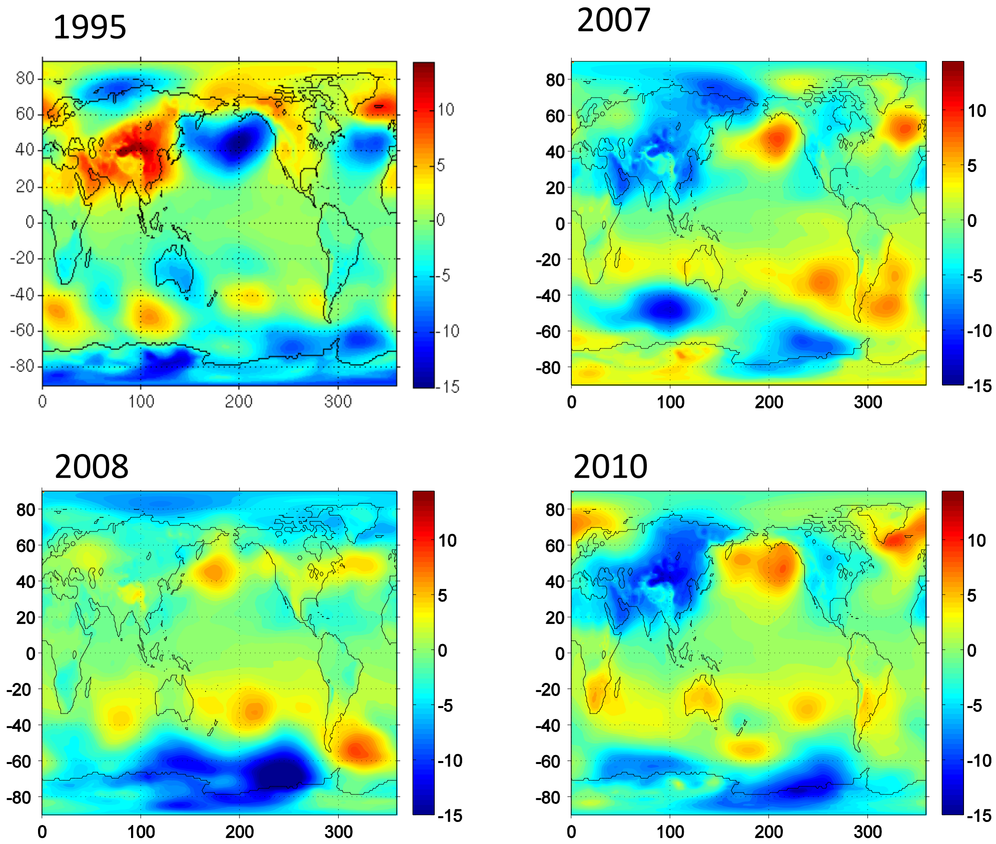

Fig. 2. 2-3 month mean sea level pressure anomaly (in HPa) observed 3-4 months before the maximum phase of the development of cold ENSO.

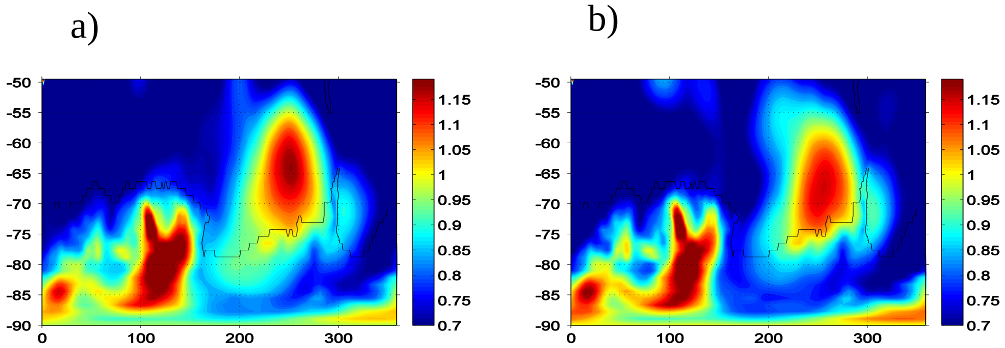

Fig. 31989-1999 (a) and 2000-2008 (b) normolized standard deviations of sea level pressure near Antarctic.