Response to Referee #2

We thank an anonymous Referee #2 for his/her thoughtful comments. We have tried to take the comments into account in the revised manuscript as follows:

SPECIFIC COMMENTS

Section 2.3 : *The description of air-sea CO_2 fluxes in the South Pacific is very short, as opposed to the other regions. This gives the impression that we know nothing about air-sea CO_2 fluxes in this region, other than suspecting it is a sink for atmospheric CO_2 based on the few data available. Is that correct ?*

A. We thank the referee for underscoring the importance of presenting what is known from previous work regarding the South Pacific. To the best of our knowledge, very little is currently known about the spatial and temporal variations of pCO_2sw in the South Pacific from the observations, nevertheless the submitted version of the manuscript failed to mention the work of Inoue et al. (1999) and Takahashi et al. (2009). These works demonstrated through their characterization of seasonal variations and the meridional distribution of pCO_2sw that the western South Pacific extra-tropics are important sinks for atmospheric CO_2 and thereby mirroring the North Pacific extra-tropics. These works also describe the secular trend towards increasing pCO_2sw in that region.

In order to provide better insight into the variation of pCO_2sw in the South Pacific, we will rephrase the section 2.3 by briefly reviewing these works as follows:

"As is the case for the extra-tropical North Pacific, the extra-tropical South Pacific is also a major sink for atmospheric CO_2 (Figs. 1 and 2). However, this region poses particular challenges to estimating air-sea CO_2 fluxes due to the paucity of pCO_2sw measurements over this vast sub-basin. The majority of pCO_2sw measurements over the South Pacific have been made in its western region but are less densely distributed than in the North Pacific, and large data gaps in space and time still exist in the eastern South Pacific (Takahashi et al., 2009a). The various gridded data products that have resulted from data synthesis activities of pCO_2sw have by necessity relied on interpolation over

large spatial scales and for seasonality in this region.

In the extra-topics of the western South Pacific, the dominant timescale of variability in pCO_2sw is likely the seasonal cycle. For the subtropical region of 20°–25°S, 165°–175°E near Vanuatu, Takahashi et al. (2009a) have shown that the amplitude of seasonal pCO_2sw variation, low in winter and high in summer, is around 40 μatm and the thermodynamic effect of seasonal SST variation is its important controlling factor. However, seasonal pCO_2sw variations have not been well documented for other regions in the extra-topics of the South Pacific. A long-term trend towards increasing pCO_2sw at +1.30 ±0.27 μatm yr^{-1} from mid-1980s to mid-2000s has also been reported in the western South Pacific near Vanuatu (Takahashi et al., 2009a). Inoue et al. (1999) have shown an increase of pCO_2sw of +41 ±9 μatm from January/February 1969 to January/February 1995 for the area 10°S–45°S, 148°E–166°E near the east coast of Australia. These observations show that the mean rate of pCO_2sw increase in the western South Pacific extra-tropics is roughly consistent with the rate of atmospheric CO_2 increase."

p12164 – lines 9-10 : *Refer to Figs.1 and 2.*

A. We will refer Figs.1 and 2 here according to the suggestion.

Section 5.3 : *The seasonal variability of air-sea CO_2 fluxes in the South Pacific is presented in Fig.9, but it is not discussed in the text.*

A. We will add a paragraph describing the seasonal variability of air-sea CO_2 fluxes in the South Pacific as follows:

"With regard to the seasonality of air-sea CO_2 fluxes over the South Pacific extra-tropics, results from the LDEO V2009 climatological pCO_2sw and two diagnostic models agreed within ±0.04 PgC yr^{-1} in all months. As in the North Pacific extra-tropics, they all show a very small net air-sea CO_2 flux in summer (February: -0.00 ±0.02 PgC yr^{-1}) and a larger influx into the ocean in winter (August: -0.56 ±0.01 PgC yr^{-1}). However, the amplitude of the seasonal cycle in the South Pacific extra-tropics is about 2/3 of that in the North Pacific extra-tropics (Fig. 9). The phase and amplitude of seasonality in the flux from the pCO_2sw data assimilation product is also consistent with LDEO V2009 and

diagnostic models. Most OBGCMs presented in this work also show well-defined seasonality with a large CO_2 sink in winter (-1.20 to -0.60 PgC yr^{-1}) and slightly negative or moderately positive fluxes in summer (-0.13 to +0.50 PgC yr^{-1}). The median ±MAD of the amplitude of seasonality is 1.15 ±0.18 PgC yr^{-1}, which is again about 2/3 of that in the North Pacific extra-tropics (1.88 ±0.40 PgC yr^{-1}). Most atmospheric CO_2 inversions also resolved the seasonality of the air-sea CO_2 fluxes in the South Pacific extra-tropics with a larger ocean CO_2 sink in winter and a smaller net flux in summer. The median ±MAD of the amplitude of seasonality is 1.01 ±0.36 PgC yr^{-1}. This is about twice as large as that from the LDEO V2009 climatological pCO_2sw and the two diagnostic models, but it agrees well with the results from the OBGCMs."

p12176 – lines 22-28 *: Could the fixed boundary at 44.5_S be responsible for the larger difference between models in the South Pacific extra-tropics than in the North Pacific extra-tropics ? The boundary issue is discussed with regards to observations, but it should also be considered for OBGCMs as the position of the frontal zone (large CO2 sink) may differ greatly from one model to the other.*

A. The referee raises a very important point here regarding the RECCAP boundaries. As a RECCAP effort, the scope of this manuscript is limited to the regional boundaries imposed through the RECCAP protocols. However, in recognition of the importance of the issue raised by the authors, the lead author is involved in a collaborative effort with one of the OBGCMs (NEMO-PISCES) to evaluate carbon exchanges in the Southern Hemisphere using a density rather than a latitude coordinate (Iudicone et al., in prep.), and the manuscript is near to being submission-ready. One of the implications of that study is that any choices of latitude as a cutoff to the South Pacific will be somewhat arbitrary and problematic, as the important frontal structures that prescribe where mode water formation forms do not follow constant latitude lines.

As the referee suggested, the position of the frontal zone (large CO_2 sink) may differ greatly from one model to the other and this may be one of the underlying causes of the discrepancies in the flux estimate among OBGCMs. Other potential causes of the discrepancies include ocean model resolution, ocean physical parameterizations, representation of ocean biogeochemical

processes, and differences in surface forcing fields as mentioned in the last paragraph of the section 6.2. However, we will not make a comprehensive analysis to identify the underlying cause of the discrepancies in detail within the context of this synthesis.

p12182 – lines 11-20 : *I don't understand the justification for calculating a "best estimate" using only 2 of the approaches. How is that consistent with the study by Lenton et al. (2013) who calculated the median of all methods ?*

A. Citation of Lenton et al. (2013) here will be removed. As is mentioned in the first and second paragraphs of section 6.2, it is clear that the synthesis of the estimates for the air-sea CO_2 fluxes do not lend themselves to a robust or quantitative path to providing a "best estimate", and we make loose use of the word here. We fully support the idea of having the community work towards an operational definition of "best estimate" as a quantitative product as part of a longer-term project, but at the same time recognize that the use of this expression may insinuate stronger quantitative grounding than what is available presently. We are optimistic that future synthesis efforts can define a "best estimate", following protocols of peer review in defining this expression and justifying this definition. We heartily recommend efforts in this direction.

p12183 – line 2 *: OBGCMs rather than OBGCs.*

A. We will correct this typo.