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## ***Interactive comment on “Historical reconstruction of ocean acidification in the Australian region” by A. Lenton et al.***

### **Anonymous Referee #2**

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This paper deals with a comprehensive view of ocean acidification in surface waters over the coastal and open zones around Australia in high resolution; presented are reconstructed maps or trends of the mean state, seasonal variability, interannual variability, and long-term trends of aragonite saturation level and pH. These are the fundamental information that we need as a basis of assessing the impact of the ocean acidification on marine ecosystem and its services. However, these mappings and reproductions are still highly challenging, given that the measurements of CO<sub>2</sub> system variables are still limited in space and time. Authors tackled this by combing a new relationship between salinity and alkalinity for this region with climatological pCO<sub>2</sub> maps they produced previously. The method and interpretations appears quite robust, but in some points they are unclear or questionable. Uncertainties and caveats need to be stated more explicitly so that the method and results presented here can serve for

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better assessments in the future. In summary, I recommend publication after a rather substantial revision based on the comments given below.

Specific comments:

- Page 8269, lines 16-19: The product of  $p\text{CO}_2$  fields given by Sasse et al (2013) is a key for this work from which the fields of aragonite saturation state and pH were derived. Explain the method and data sources of its updated version in more detail, and describe the uncertainty in the estimates.

- Page 8270, line 8 (Eq(1)): In the southern rim of the region (40S-50S), the alkalinity –salinity relationship of Eq(1) appears to give significantly smaller values of surface alkalinity than those from previous studies (Lee et al., *Geophys. Res. Lett.*, 33, L19605, doi:10.1029/2006GL027207, 2006; Takatani et al., *J. Geophys. Res., Oceans*, 119, doi:10.1002/2013JC009739, 2014). The difference may reach to 30  $\mu\text{mol/kg}$ , resulting in the large differences in aragonite saturation state and pH. I suggest authors to incorporate the data of total alkalinity from 40S-50S taken at Repeat Hydrography Sections SR03 and I09S, and reevaluate Eq(1). High-quality data of total alkalinity around Australia are also available from sections I05, P21, and P06 (<http://cdiac.ornl.gov/oceans/RepeatSections/>). Surface alkalinity data from TF5, the main data source of analysis for Eq(1) (Table 1 and Figure 3), are not available from the website indicated in the footnote of Table 1. Correct the quotation.

- Page 8272, lines 8-22, and Figure 4: Compare also the reconstructed pH with values calculated from observations. The sensitivity to temperature change shall be quite different between aragonite saturation state and pH. The time-series plots of pH also help to understand the phase of seasonal variation. The uncertainties in the reconstructed aragonite saturation state and pH as derived from the uncertainties in the reconstructed  $p\text{CO}_2$  and TA should be also given.

- Page 8273, lines 25-28: I suspect the interpretation here. The distribution of aragonite saturation state and pH are also set by the large-scale variation of DIC. I presume that

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a relatively low pH in the tropical region is driven by warmer temperature. On the other hand, the decrease of pH south of Australia is driven by the elevation of DIC/TA increase, although this tendency may have been biased because of the underestimation of TA by Eq(1).

- Page 8274, lines 16-19: I don't understand this sentence. I guess the seasonal variation in DIC should be also taken into account. It appears to me that the seasonal variations of pH and aragonite saturation state along the east coast of Australia and in the Tasman Sea are controlled by the interplay between DIC/TA and SST.

- Page 8276, lines 6 - Page 8277, lines 6; Historical changes: This method assumes constant  $\Delta p\text{CO}_2$  over the time period of 1870-2013 (P9269, L20-24). When combining this assumption with the atmospheric  $\text{CO}_2$  record, this will give the upper limit of DIC increase and thereby the upper limits of aragonite saturation state decrease and pH decrease associated with the atmospheric  $\text{CO}_2$  rise. In the western South Pacific, this assumption has been only weakly constrained by the observations over the past a few decades (Takahashi et al., Deep-Sea Research II, 56, 554-577 (2009); Inoue et al., Tellus, 51B, 830-848 (1999)). In addition, changes in ocean circulation and mixing potentially have a large impact on these trends. These caveats should be addressed in the text.

- Page 8277, lines 7 - Page 8278, lines 9; Interannual variability: In reality, IAV of aragonite saturation state and that of pH have been controlled by the IAVs of DIC and TA as well as those of temperature and salinity. However, if I understood the method correctly, the IAV presented in Figs. 7 and 8 is in principle the IAV of the thermodynamic effect of SST on aragonite saturation state and pH at isochemical condition (climatological DIC + climatological S + climatological TA) and does not represent the effect of IAVs of DIC and TA. Does it make sense to compare the IAV of just SST's thermodynamic effect with the seasonal variations shown in Fig.5? The amplitude of seasonal variation of DIC has not been shown in this paper, but Lee (Limnol. oceanogr., 46, 1287-1297, 2001) suggested that it ranges from 15  $\mu\text{mol/kg}$  in the northern to 50  $\mu\text{mol/kg}$  in the

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southern Australian waters. This implies that IAV of DIC is also significant.

Minor points:

- Page 8271, lines 13-15: Specify that the pH and carbonate saturation state were calculated at in-situ temperature.
- Figure 1, 3, 4, and 8: It will be convenient for readers if the acronyms of the station name given in Figure 1 are also used in Figures 3, 4 and 8 and in the text.
- Page 8274, line 9: not “>0.6” but “>0.06”.
- Page 8274, line 26 “. . . sea surface salinity driving changes in total alkalinity. . .”: The change in sea surface salinity drives the change in DIC as well.
- Page 8276, line 22: (typo)“in in”.
- Page 8276, line 25: “Fig. 8”, not “Fig.10”.

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