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Biogeosciences Discussions

Interactive comment on "High temporal and spatial variability of dissolved oxygen and pH in a nearshore California kelp forest" *by* C. A. Frieder et al.

Anonymous Referee #2

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General comments:

Frieder et al. present a well-designed observational study of an ecologically-important nearshore ecosystem. In general, the paper is well written and contributes valuable information that will improve our understanding of biogeochemical variability in coastal systems, the impact of this variability on marine organisms, and how changing ocean chemistry may impact marine systems in the future. The combination of spatial and temporal design of the observations will be particularly valuable to better understanding the dynamic nearshore environment. However, the authors need to be more thorough in describing how the pH data collected in this study relate to ocean acidification (see

specific comment #1 below). The paper would also be much improved with additional discussion of recent published research on ocean carbon variability, high-CO2 impacts on kelp, and future predictions of upwelling in the CCS (see specific comments #s 2&3 below).

Specific comments:

1) In order to constrain the ocean carbonate system, 2 of the 4 possible parameters must be directly measured (along with temperature, salinity, and pressure) or estimated using robust empirical relationships with other measured parameters. Recently, the international ocean acidification observation community defined constraint of the carbonate system as a minimum requirement of an observational site for understanding ocean acidification conditions (report to be released in fall 2012: http://www.pmel.noaa.gov/co2/OA2012Workshop/WorkshopHome.html). This is increasingly important when attempting to link ocean acidification conditions to species response as there is increasing evidence that organisms are impacted in different ways by different carbonate system constituents (e.g., pH, pCO2, Ωaragonite, or Ωcalcite; see Fabry et al. ICES J. Mar. Sci. 2008 and Doney et al. Ann. Rev. of Mar. Sc. 2009). Full constraint of the carbonate system is also critical for defining the uncertainty of autonomous sensors, as used in this study. Frieder et al. allude to the need for high-quality carbonate chemistry data in lines 2-4 in the Abstract; however, they go on to present only pH data and conclude that kelp forests may provide temporary refugia from ocean acidification, even though ocean acidification conditions have not been defined in this ecosystem. This issue could be addressed by one of the following:

a. Include a more detailed discussion about the limitations of using only pH measurements to assessing ocean acidification conditions and attributing impacts, as described above.

b. Estimate temporal and spatial variability of pCO2 and Ω using discrete TA and DIC validation data (if the temporal and spatial extent of discrete sampling is sufficient to do so). The authors may also want to explore whether it is possible to use the algorithms developed by Alin et al. JGR 2012 for the southern CCS to estimate carbonate system parameters. This may not be ideal for nearshore waters, but it's possible the algorithm could work in deep water using pH, DO, and SSTC measurements made in the kelp forest. This could be tested by comparison to discrete samples made during the study.

2) The authors make the conclusion that "these findings raise the possibility that the benthic communities along eastern boundary current systems are currently acclimatized and adapted to natural, variable, and low DO and pH" (lines 26-28 of abstract). While this may be true, this paper should include additional discussion on variability, with references to studies that have observed variable pH at other coastal sites (e.g., Feely et al. Estuar. Coast. Shelf Sci. 2010, Yu et al. J. Exp. Mar. Bio. Ecol. 2011, Cai et al. Nature Geo. 2011, Cullison Gray et al. Mar. Chem. 2011) and how variability may change if anthropogenic CO2 continues to increase into the future. For example, in a review by Pelejero et al. TREE 2010, there is a discussion of examples of pH variability over different timescales (see Figure 1 in the review). If variability changes over time, it is not clear whether marine organisms will respond to some threshold in pH, a decreasing mean over a long time period, lower minimum values, larger fluctuations in pH, or increased exposure to episodic extreme low pH values (or a combination of these). This discussion is critical, especially when comparing pH ranges observed in this kelp forest to open ocean waters (lines 12-13 in Abstract and 3-4 in section 4.2), which naturally have a smaller range than coastal waters; without that discussion, these statements comparing nearshore and open ocean systems are out of context and confusing and should be removed (or modified). The statement about the acclimatization of benthic communities should also be considered in the context of predictions of bottom water undersaturation in the CCS by Gruber et al. Science 2012.

3) The paper would be much improved with additional discussions of research findings on high-CO2 impacts on kelp and potential changes to future upwelling. Reference is made to macrophyte-based ecosystems being refugia to deoxygenation and acidifica-

tion (lines 16-17 Abstract); however, there should be some discussion in the Introduction or section 4.4 on potential impacts of changing chemistry on kelp (or macrophytes in general; e.g., increased photosynthesis due to increasing pCO2). Some potential citations: Hepburn et al. Glob. Chang. Bio. 2011, Connell and Russell P. Roy. Soc. B-Bio. Sci. 2010, Beer and Koch MEPS 1996, and there may be others. Reference is also made to future intensifying of upwelling (lines 29-30 Abstract and 12-13 section 4.4), but there is no explanation of this potential phenomenon. This is described by Bakun and Weeks Ecol. Lett. 2004 and Bakun et al. Glob. Chang. Bio 2010 and should be cited and discussed in those sections of the paper.

Technical corrections:

1) lines 8-9 Introduction: Ocean acidification is not only decreasing pH but decreasing saturation states as well.

2) line 21 section 2.2: Were discrete samples taken at deployment and recovery to define sensor drift, if any?

3) line 28 section 2.2: Define constants used in CO2SYS here.

4) line 21 section 4.2: Del Mar buoy should be defined earlier – it appears as "DM buoy" in previous sections.

5) line 9 section 4.3: P:R is defined here, but should be defined in earlier sections.

6) lines 26-27 section 4.4: I believe there is experimental evidence that some organisms actively buffer sites of calcification, such as in shellfish and corals (Cohen and Holcomb Oceanogr. 2009)

7) lines 16-17 section 4.4: Gruber et al. Science 2012 have demonstrated this in CCS models. Should be referenced to here.

8) Figure 9: This figure is a bit confusing. Why isn't the ΔpH and ΔDO ranges as large as the ranges observed during this study?

Interactive comment on Biogeosciences Discuss., 9, 4099, 2012.