

Interactive comment on “Rate of Iceland Sea acidification from time series measurements” by J. Olafsson et al.

Anonymous Referee #2

Received and published: 27 July 2009

General comments: This paper presents unique and important data on the acidification of seawater in the Iceland Sea based on winter time measurements between 1985 and 2008. The data and results are of outmost importance and should be published. However, the current version of the paper could be improved by some restructuring of some of its content, clarification of a few unclear sections, expanding on the discussion, and making a number of corrections to a few conceptual errors as well as the wording in a few places of the text (see specific comments). I think the paper would benefit from having a clearer structure in terms of methods, results and discussion. In its current format results and discussion are randomly integrated. I also think the methods section would be clearer if it had a separate subsection on the collection and analytical methods, which in the current version is only briefly mentioned. The authors may also consider presenting the observed changes in $[\text{CO}_2^-]$, since both Omega-aragonite

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and Omega-calcite are functions of this concentration (ultimately, the authors would submit all the data as supplementary material, i.e., T,S,TCO₂,pCO₂). The discussion of the results is very brief and I suggest further elaboration on the potential consequences of the shoaling of the saturation horizon, e.g., the potential effects on the benthos, at what depth will the saturation horizon be located at, for example, in year 2100, do the observed changes in seawater chemistry agree with expectations based on the increase of CO₂ in the atmosphere, etc. However, overall this is a good and important paper that should get published.

Specific comments: Abstract:

P5252, Line 5: Monitoring CO₂ concentration in seawater for changes in response to increasing atmospheric CO₂ – Do the observed changes agree with the anticipated changes based on the observed increase in the atmosphere?

P5252, line 9: Suggest addition: “Surface seawater carbonate saturation state. . .” and “. . .1/2 those for subtropical surface waters.”

P5252, 13: suggest using the term “shoaling” rather than “rising.”

P5252, line 13-15: the last sentence in the abstract is awkward and needs to be rewritten. I suggest something along the lines of: “Based on this rate of shoaling of the aragonite saturation horizon and the local hypsography, 800 km² of seafloor becomes exposed to undersaturated conditions with respect to aragonite each year.

Introduction:

P5252, line 20: Suggest rewrite: “It is located north of Iceland and divided by the Kolbeinsey Ridge into two basins, the western part being shallower. . .”

P5253, line 8: Suggest addition: “. . .due to anthropogenic emissions of this gas.”

P5253, line 11: Suggest addition: “. . .trends toward lower seawater pH and. . .”

P5253, line 17: “As the carbonate ion concentration is lowered, the solubility of calcium

carbonate, CaCO_3 , increases.” This statement is not correct. The solubility (i.e., K_{sp}) of calcium carbonate is unaffected by changing $[\text{CO}_3^{2-}]$. The solubility is a function of T, S, P. The seawater saturation state with respect to calcium carbonate is affected by the change in $[\text{CO}_3^{2-}]$ but not the solubility.

P5253, line 22: suggest rewrite: “. . .when seawater is in equilibrium or at saturation with respect to a calcium carbonate mineral phase. . .”

P5254, line 1: suggest rewrite: “. . .where the subscripts “sw” and “sat” refer to the in situ seawater concentration and the concentration at saturation, respectively.”

P5254, line 5: See also Andersson et al., 2009, Life on the margin: implications of ocean acidification on Mg-calcite, high latitude and cold-water marine calcifiers, MEPS, 373, 265-273.

P5254, line 10: “Recently another ocean-carbon-climate model study. . .” Need to add reference to this study.

Methods:

I suggest a separate subheading on the analytical methods and a little bit more detail on the collection and analysis of pCO_2 and DIC of the seawater samples. Currently, this is included in the Data processing subheading and feels somewhat out of place.

P5255, line 28: Change apparent dissociation constants to stoichiometric dissociation constants. Mehrbach et al. (1973) as refit by Dickson and Millero (1987) is stoichiometric and not apparent.

P5256, line 21: Change apparent to stoichiometric.

P5256, line 23: Suggest adding: “. . .with pressure, temperature, and salinity corrections.

Results:

P5257, line 15-18: Suggest rewrite: “At two subtropical Atlantic time-series stations, BATS near Bermuda and ESTOC near the Canary Islands, the observed rate of surface seawater pH decline is slower, -0.0017 pH units yr⁻¹, and the corresponding [H⁺] increase smaller, 9%, compared to the Iceland Sea (Bates 2007; Santana-Casiano et al. 2007).”

P5257, line 20-25: The discussion on the temperature effect is somewhat confusing and needs to be clarified.

P5257, line 25: Suggest writing the rate as -0.0022 pH units yr⁻¹ to make it clear what it refers to.

P5258, line 6-7: “We evaluate the changes in carbonate chemistry of deeper water from deep observations. . .” How would it otherwise be evaluated? Needs rewrite.

P5258, line 12-23: The discussion on the effect of pressure on the solubility of calcite and aragonite as well as pH is unclear. Suggest significant rewrite to clarify this section.

P5259, line 11: Why is the aragonite saturation horizon so much shallower in the Iceland Sea than in the Arctic?

P5259, line 18: Suggest giving example of some the benthic biota that have become immersed in waters undersaturated with respect to aragonite? Are there any Mg-calcite producers?

P5259, line 19: Suggest rewrite “Our data from both east and west of the. . .”

P5259, line 26: Correct error “. . .BATS it was then. . .”

P5259, line 27: Suggest rewrite: “. . .reduction in pH would be greater in the Iceland Sea surface water.”

P5260, line 3: Correct units to $4.5 \text{ mol m}^{-2} \text{ y}^{-1}$. P5260, line 3: Suggest rewrite: “. . .(J. Olafson, unpublished data). . .”

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P5260, line 10: suggest delete “anyway”

P5260, line 10: “In the deep water, the pressure effect adds to the low temperature, and above the depths of 1500 m, the aragonite saturation horizon is shoaling. . .” It is unclear what the authors are trying to say in the first part of this sentence. Suggest rewrite.

Table 1. Suggest writing saturation states rather than saturation stages in caption. Also, are all the significant figures necessary?

Figure 3. Show in figure and in caption that pH is on the total scale.

Figure 5. Based on the estimated rate of shoaling of the saturation horizon of 4 m per year, it would be informative to show a time-scale on the right x-axis corresponding to the depth of the saturation horizon in a particular year starting from present.

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