Biogeosciences Discuss., 11, C2132–C2137, 2014
www.biogeosciences-discuss.net/11/C2132/2014/

Biogeosciences
Discussions
Open Access

Interactive comment on "Modeling coral calcification accounting for the impacts of coral bleaching and ocean acidification" *by* C. Evenhuis et al.

P. Jokiel (Referee)

jokiel@hawaii.edu

Received and published: 10 June 2014

This Evenhuis et al. article presents an advanced model of coral calcification built on existing paradigms with a series of important new innovations. Parameter values used in the model are based on a synthesis of existing observational and experimental data. The resulting model improves our ability to mathematical describe and predict changes in coral calcification rate during a time of climate change. Their new model is an improvement over previous models that have been developed to show impact of future ocean acidification and temperature change, and sets the stage for future advancements in modeling. I agree with their conclusion that despite the implicit complexity of the coral reef environment a simple model based on temperature carbonate chemistry and different species can reproduce much of the observed response of corals to changes in temperature and ocean acidification. The model is “state of the art” and paves the way for future efforts.

Several simplifying assumptions that eventually will need to be addressed in future versions of this model.

Assumption 1. Coral reef calcification rate = Coral calcification rate. This assumption has limits because corals can continue to grow relatively well at levels of ocean acidification that result in net dissolution of a coral reef (Andersson et al. 2009). Important reef calcifiers such as crustose coralline algae (CCA) are far more sensitive to OA condition than corals and can be eliminated from the reef at OA levels that still allow substantial coral growth (Kuffner et al. 2008). There are many reefs in the world that are dominated by CCA, with a very small component of live coral. Another related issue is that coral growth is generally measured directly by change in weight or linear extension while reef calcification is generally measured by the alkalinity depletion method (Kinsey 1978, Smith and Kinsey 1978). The alkalinity depletion method measures net calcification and includes the substantial alkalinity contribution of dissolving carbonate sediment and rocks (Murillo et al. 2014) as well as contributions from other components such as macroalgae, crustose coralline algae, sediment diagenesis, etc. The authors recognize that Assumption 1 is necessary until we can produce enough data on the other components to refine the model. However, coral growth (weight change) cannot realistically be regarded as net reef calcification (alkalinity depletion method) although there must be a correlation. So the method will be useful in further defining and refining trends in coral reef response to global climate change, but with several caveats as mentioned above.

Assumption 2 is that calcification rate is driven by bulk water carbonate ion concentration. Aragonite saturation state is a function of carbonate ion concentration. Assumption 2 is not correct (Jokiel et al. 2014). Carbonite ion concentration (and thus aragonite saturation state) of bulk water in laboratory incubations or in field flow metabolism experiments increases with increasing calcification rate, so carbonate ion concentration (or aragonite saturation state) cannot possibly be limiting (Jokiel 2014). Aragonite saturation state lags calcification by two hours (Shamberger et al. 2011, Jokiel et al. 2014) so cannot be driving calcification. However, there is a correlation between the two. The slope and intercept of the correlation varies from reef to reef. The calcification rate of reefs is driven primarily by photosynthetic rate of the calcifying component (available light) and limited by proton efflux from the corals (Jokiel 2014). A major issue here is that if G is measured using the alkalinity depletion method the result is greatly modified by dissolution rate of carbonates, changes in pH due to photosynthesis and other factors. Thus we find no consistent relationship. Many reefs with low aragonite saturation state show high rates of coral calcification (e.g. Shamberger et al. 2011, 2014). The Evenhuis et al. model skilfully manipulates the aragonite saturation data that are presently available as a means of empirically describe the relationship between the aragonite saturation state of seawater and G. Eventually more data on response of various components to temperature and OA will become available and the model can be modified using the true drivers of net calcification. The use of irradiance (Q) as a major component of the equation resolves part of the issue because Pnet of the calcifying photosynthetic organisms drives Gnet (Jokiel et al. 2014) and these systems are very efficient at using all of the available irradiance through canopy development (Jokiel and Morrissey 1986) and other photo-adaptive processes.

Use of these assumptions is appropriate due to the lack of data on the various other components of a calcifying reef system (e.g. impact of temperature and OA on sediment and coral rock dissolution, effects of crustose coralline algae). However, understanding the potential impact of these assumptions is critical to interpreting and applying the results to real world situations. More data will be developed on response of the calcifying organisms, bioeroding organisms, macroalge, etc. as well as response to dissolution rates of carbonate sediments and rock to increased temperature and increased OA. More data will be needed on the actual biomass and reef areas involved.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

This will be developed further in future studies.

According to this model the calcification rate (G) depends on five factors:

1. The level of light (Q) per day. This is an excellent feature. Q is easily calculated and drives Pnet which drives Gnet (Jokiel et al. 2014). Coral reef systems have evolved to efficiently us the photons that are available.

2. Sea surface temperature. There are existing data that allow linking temperature to coral growth and the use of fitting a second order polynomial to describe the growth response is well established (Buddemeier et al. 2008). It is more difficult to link degrees heating metrics to the changes in growth and mortality that result from stress among the different species response or to account for thermal adaptation. The empirically derived relationship of mortality and reduced growth in relation to bleaching due to extreme temperatures has been modeled by the degree heating week or month metrics e.g. Their model shows the importance of annual temperature range as well as the bleaching threshold in determining the bleaching sensitivity and annual physiological performance of corals.

3. Whether the species is fast or slow growing (Csp) Empirically derived.

4. The population of healthy corals (PH). Empirically derived.

5. The aragonite saturation state. The problem with use of omega is discussed above under the heading of Assumption 2. Although omega does not drive coral calcification it does show a correlation. omega is a dependent variable on G, pH, dissolution rate of the surrounding reef carbonates. Therefore the slope and intercept of the G vs. omega relationship varies widely over spatial and temporal scales. The authors have worked around this problem by using a mean of all observed values, which is appropriate for now. Correlation does not prove cause and effect, but can be used for a first approximation of the relationship until we can derive the needed data.

This paper shows creative innovations in the application of the Arrhenius equation to

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

show enhancement of biological and chemical reactions with increasing temperature. The model takes into account thermal specialization among the different coral species adaption to local environment. The purpose of models is to synthesize available information in order to define relationships, predict and identify what data are needed to expand the model. The Evenhuis et al. model represents a great advancement in this area and should be published.

Paul Jokiel

Andersson AJ, Kuffner IB, Mackenzie FT, Jokiel PL, Rodgers KS, Tan A (2009) Net loss of CaCO3 from coral reef communities due to human induced seawater acidification. Biogeosci Discuss 6:1–20.

Buddemeier, R. W., P.L. Jokiel, K.M. Zimmerman, D.R. Lane, J. M. Carey, G.C. Bohling, J.A. Martinich. (2008) A modeling tool to evaluate regional coral reef responses to changes in climate and ocean chemistry Limnol. Oceanogr.: Methods 6:395–411 Jokiel PL, Morrissey JI. (1986) Influence of size on primary production in the reef coral Pocillopora damicornis and the tropical macroalga Acanthophora spicifera. Mar. Biol. 91:15-26.

Jokiel PL, Jury CP, Rodgers KS (2014), Coral-algae metabolism and diurnal changes in the CO2-carbonate system of bulk sea water. PeerJ 2:e378; DOI 10.7717/peerj.378 Kinsey D (1978) Alkalinity changes and coral reef calcification. Limnol Oceanog 23(5):989-991

Kuffner IB, Andersson AJ, Jokiel PL, Rodgers KS, Mackenzie FT (2008) Decreased abundance of crustose coralline algae due to ocean acidification. Nature Geoscience 1: 114-117 Murillo LJA., Jokiel PL, Atkinson MJ (2014) Alkalinity to calcium flux ratios for corals and coral reef communities: variances between isolated and community conditions. PeerJ 2:e249, DOI 10.7717/peerj.249

Shamberger KEF, Feely RA, Sabine CL, Atkinson MJ, DeCarlo EH, Mackenzie FT,

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

Drupp PS, Butterfield DA (2011) Calcification and organic production on a Hawaiian coral reef. Mar Chem 1271–4:64–75. doi:10.1016/j.marchem.2011.08.003.

Shamberger, KEF, Cohen AL, Golbuu Y, McCorkle DC, Lentz SJ, Barkley HC (2014) Diverse coral communities in naturally acidified waters of a Western Pacific Reef. Geophys Res Lett 41, doi:10.1002/2013GL058489.

Smith SV, Kinsey DW (1978) Calcification and organic carbon metabolism as indicated by carbon dioxide. In Coral Reefs: Research Methods, Stoddart DR, Johannes RE (eds) Monographs on Oceanographic Methodology Series, UNESCO, Paris, 5:469-484

Interactive comment on Biogeosciences Discuss., 11, 187, 2014.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper