Reviewer 2

Page numbers in referee responses refer to pages in the revised manuscript. Responses to reviewer comments are in blue.

The manuscript addresses the fluxes of TA from ground water and pore water to coral reef lagoon in the Cook Islands. The methods for quantifying the fluxes seem reasonable although I would guess that removing a 150 ml sample from the chamber with simultaneous seawater replacement could lead to mixing that will alter the TA of sample either up or down depending on whether the TA of the seawater is higher or lower than the chamber water.

We recognize that replacing sample volume from the chambers with water from the water column could affect solute concentrations within the chambers. We addressed this comment by adding the following text to the methods:

(p. 9, line 1) "The sample volume removed represented a minor percentage of the volume within the chambers (< 4%) and the chemical composition of the overlying seawater was similar to the water within the chambers, and therefore was unlikely to greatly influence chamber solute concentrations."

The chamber advective pore water and ground water flux measurements were made at a single location. Observations were made over a single 28 hour period. I realize that these measurements are state of the art and very difficult to make but the introduction stresses that these fluxes can be quite variable in time and space and that leaves me wondering how much confidence should be attributed to the daily fluxes that result from this study and I further wonder about whether there is justification for extrapolating the flux measured at one location to the entire lagoon.

We recognize that SGD and benthic fluxes can be variable both temporally and spatially. This study focused on small temporal variations, and in order to sample at such high resolution we couldn't sample across broad spatial scales. The fluxes were extrapolated in order to compare SGD and advective processes over an ecosystem scale. In order to address these issues we added the following text to the manuscript:

(p. 22, line 20) "It is important to constrain the variability of these fluxes of larger temporal and spatial scales across coral reef environments."

(p. 20, line 16) "Because the flux rates of these benthic processes were variable temporally and spatially any extrapolation needs to be taken with care. In order to compare the two sources of groundwater and their influence on TA concentrations in the lagoon, a 750 m x 1 m transect was projected from the sampling site to the reef crest (Fig. 1). The flow of water in the lagoon is generally from the reef crest towards shore, therefore any changes in the water column chemistry would occur along this transect."

(p. 20, line 23) "Since currents are the main driver of porewater advection, the different stirring rates would likely reflect any variability within the lagoon."

(p. 20, line 12) "Also, any seasonal variability in rainfall may influence SGD flux rates over larger temporal scales."

The authors estimate a ground water TA flux of 1080 mmol/m2/d. This flux dwarfs the advective pore flux of -1.6 to 7.8 mmol/m2/d.

We agree that the SGD derived daily flux rate seems large, however, we believe they are correct based on the observed changes in water column TA. We added the following text to the manuscript in order to address this comment:

(p. 18, line 21) "These fluxes are high when compared to other TA sources and sinks in coral reef environments (Gattuso et al., 1998;Shamberger et al., 2011). However, the hourly flux rates agree well with flux rates that are needed to explain the observed changes in water column TA concentrations. Flux rates needed to account for the observed increases in TA concentrations during the day were as high as 103 mmol m^{-2} hr^{-1}. These values are comparable to the SGD derived TA fluxes calculated from the ^{222}Rn mass balance and groundwater alkalinity concentrations, which ranged from 0 to 105 mmol m^{-2} hr^{-1} (Fig. 11B). The fact that these two calculations, which were derived from independent methods, agree well lends support to hourly and daily ^{222}Rn derived SGD TA fluxes. Also, TA concentrations at our study site were elevated (up to 2608 µmol L^{-1}; Fig. 4) when compared to TA concentrations in other coral reef lagoons (~2100 to 2400 µmol L^{-1}) (Shamberger et al., 2011;Shaw et al., 2012;Silverman et al., 2012;Cyronak et al., 2013) and the nearby Pacific Ocean (~2300 µmol L^{-1}) (Millero et al., 1998). This lends support to an external source of TA into the Rarotonga lagoon."

The TA demand for corals in typical lagoonal environments from Kinsey 1983 is 26-42 mmol TA equiv/m2/d. This is far lower than the 400 mmol/m2/d that the author's assume. By the way this number seems high even for reef flat environments. A review of recent papers gives Shamberger et al. 2012 Kanehoe Bay 236-292, Falter et al. 2012 Ningalo Reef 380, Silverman et al. 2012 One Tree Is 148, Shaw et al Lady Elliot Is 290, Gattuso et al. 1998 give an average of 14-340 mmol TA equiv/m2/d.

We believe that our attempt to be concise may have caused confusion with the units being used. Most studies report calcification rates as carbonate deposition, which is equal to half the uptake of TA (Kinsey 1978). Because we are dealing with TA concentrations in the water column, we converted calcification rates to mmolTA/m2/d. We also compared groundwater fluxes of TA from our study to whole ecosystem fluxes of TA in the literature instead of extrapolating coral cover (text shown later). We added the following text to clarify:

(p. 4, line 11) "Because CO_3^{2-} is equal to 2 TA equivalents, calcification rates are equal to half the change of TA concentrations."

Given the residence time of 6 days that the authors estimate and the slow removal rate by coral calcification if the ground water TA flux is really 1080 mmol/m2/d the TA in the lagoon waters would be very much higher than the observed 2350-2550 umol/L. Either the residence time is very much shorter than estimated or the ground flux has been greatly over estimated. Since a six day residence time in a lagoon seems reasonable I left to conclude that the ground water flux can not be as great as 1080 mmol/m2/d. It would have been good if the offshore TA had been measured but it likely about 2350. The fact that the average TA of lagoon waters exceeds this value supports a flux of TA into the system from somewhere that exceeds the calicification rate of the system. Lagoons typically have quite low calcification rates with Kinsey 1983 finding that they fall in the 26-42 mmol TA equiv/m2/d range. Therefore a groundwater TA flux of >50 mmol/m2/d would be believable but not 1080.

We agree that the SGD derived fluxes seem large on a square meter basis. However, SGD discharge is unlikely to be occurring throughout the entire lagoon, and TA flux rates of that magnitude are most likely only occurring close to shore. The advective fluxes, on the other hand, are occurring throughout the lagoon, as the benthic environment is dominated by carbonate sands. It was necessary to extrapolate the fluxes along a transect to the reef crest in order to fairly compare their influences on lagoon TA concentrations. When both the SGD and advective fluxes are combined along the transect, they result in a daily TA flux of 62.1 to 72.9 mmol/m2/d, which is similar to what the reviewer expected, and would explain the elevated TA concentrations within the lagoon. In order to address this point in the manuscript we added the following text:

(p. 21, line 4) "Combined TA flux rates from both SGD and pore water advection along the 750 m transect were between 62.1 and 72.9 mmol m^{-2} d^{-1}, which is above the TA uptake rates of coral lagoons (26-42 mmol m^{-2} d^{-1}) as measured by Kinsey (1983). These flux rates are consistent with the elevated TA concentrations measured at our sampling site. Across the 750 m transect, groundwater (from both porewater advection and SGD) contributed 46.3 to 52.8 mol TA d^{-1} to the water column. On a daily basis, pore water advection fluxed from 1.6 to 3.5 mol TA d^{-1} into the lagoon, while SGD fluxed 50 mol TA d^{-1} along the 750 m transect."

(p. 22, line 16) "The daily SGD derived TA flux is high when compared to other sources and sinks, however groundwater is likely discharged only a discrete distance from shore."

(p. 21, line 45) "Previous studies have estimated coral reef community calcification rates to range from 31.2 to 292.8 mmol CaCO3 m^{-2} d^{-1} (or -62.4 to -585.6 mmol TA m^{-2} d^{-1}) (Shamberger et al., 2011). Using that range of community TA uptake estimates along the 750 m transect reveals that porewater advection can account for up to 2% of community TA uptake, or contribute up to 12% of the TA taken out of the water column. SGD derived TA fluxes can add from 12% to 115% of the TA taken up by coral communities. The community TA uptake rates of coral lagoons is generally low compared to other reef ecosystems (Kinsey, 1983), which means it is likely that SGD contributes towards the higher end of that range. This is consistent with the elevated TA concentrations at our study site. This previously unaccounted for TA is important in changing the carbon chemistry within Muri Lagoon over tidal and diel cycles."