Deposit Item, Supplementary Information

Oceanographic data adjustments using seawater potential density

Oceanographic data were adjusted as the CTD casts and discrete bottle samples only provide a depth-based snapshot of mid-water environmental conditions. While sessile benthic organisms like octocorals are fixed at depth, oceanographic parameters are tightly fixed to density-specific water masses, which can undergo constant vertical oscillations from physical forcing, thereby exposing octocorals to a range of environmental conditions over short timescales. Inertial oscillations in seawater masses are apparent through high-resolution temperature data collected from Kailua-Kona, which can be driven by factors such as lunar tides and larger mesoscale eddies. Such oscillations also visibly attenuate with increasing depth and can influence oceanographic measurements conducted at a fixed depth depending on the time of sampling. The temperature time-series data, as well as correlations between temperature and potential density (σ_θ, kg/m^3) from the CTD casts, provided insight on the magnitude of water mass oscillations over different depths and times and allowed for CTD measurement adjustments. A temperature and σ_θ correlation converted high-resolution temperature data over multiple depths into high-resolution σ_θ data which was then averaged by depth over a 24-hour composite period (e.g., changes in σ_θ relative to mean σ_θ ($\Delta\sigma_\theta$) as a function of time of day). The depth and timing of specific oceanographic measurements were inserted into the 24-hour averaged curves to calculate $\Delta\sigma_\theta$. A more accurate σ_θ ($\sigma_{\theta,\mathrm{True}}$) was then calculated through

$$\sigma_{\theta,\mathrm{True}} = \sigma_{\theta,\mathrm{Measured}} + \Delta\sigma_\theta \tag{S1}$$

which approximated a more accurate corresponding oceanographic parameter depending on the relationship between said parameter and $\sigma_{\theta,\mathrm{True}}$.

Temperature data from multiple depths ranging from 220 to 900 m depict short-term (M_2 semidiurnal tidal cycles; Merrifield and Holloway 2002) and long-term (mesoscale eddies; Calil et al. 2008) variability resulting from the oscillations of water masses with different densities over a yearlong interval ([1]Fig. S2). Deviations from the average potential density were relatively small (~0.01 kg/m^3 at most) and resulted in few adjustments in depth-based oceanographic data ([1]Fig. S5). Power spectral density analysis revealed consistent tidal patterns dominated by the M_2 semidiurnal tide, which decreased rapidly with increasing depth ([1]Fig. S6). Average temperatures decreased rapidly after the 220 m logger (average temperature of 16.29 ± 1.32 °C compared to 11.02 ± 0.79 °C from 302 m) but then stabilized at 506 m and greater (6.80 ± 0.29 °C).

LA-ICPMS Reference Materials

For LA-ICPMS measurements, the reference material NIST SRM 612 was used as an external standard, with the reference materials coral powder JCp-1 and giant clam powder JCt-1 (National Institute of Advanced Industrial Science and Technology, Tsukuba, Japan) measured to confirm accuracy. The reference materials were analyzed three times before and after every 50–100 sample spots to monitor instrument drift. The Mg/Ca ratio calculations were based on the analyses of NIST SRM 612, standard glass, and reproducibility (percent relative standard deviation [%RSD]), measured at <5%. The Mg/Ca ratio of JCp-1 (certified value of Mg/Ca = 4.2 mmol/mol) was determined to be Mg/Ca = 4.5 ± 0.2 (1σ, N = 26) mmol/mol. Detailed analytical conditions are reported in the literature (e.g., Murakami-Sugihara et al. 2019).

Raman measurements of octocoral Mg and FWHM using the ν_1 peak

The ν_1 peak is the strongest in the Mg-calcite spectrum and has been measured in numerous studies of biogenic aragonite (Kamenos et al. 2013, 2016; Hennige et al. 2015; Pauly et al. 2015; DeCarlo et al. 2017, 2018, 2019; Comeau et al. 2018; Cornwall et al. 2018, 2020; Farfan et al. 2018, 2021) and Mg-calcite (Bischoff et al. 1985; Urmos et al. 1991; Borromeo et al. 2017; Comeau et al. 2018; Cornwall et al. 2018, 2020). ν_1 has also been measured for amorphous calcium carbonate (Wang et al. 2012) and was noted by Borromeo et al. (2017) to be the most reliable peak (along with ν_4) for distinguishing Mg content in biogenic calcites. While the ν_1 peak is a non-degenerate (singlet) peak corresponding to the symmetric stretching vibrational mode of oxygen with respect to the carbon atom, high Mg content (~30 mol%) is known to cause asymmetry in the ν_1 peak leading to the fitting of two peaks (Perrin et al. 2016 supplementary materials). However, the octocoral Mg content measured in this study does not exceed 14.5 mol%, meaning that the ν_1 peak doubling phenomenon and resulting inaccuracies in fitting Raman shift and FWHM parameters should be minimal.

The intensities of the Raman spectral lines are sensitive to crystallite orientation within the analyzed sample. However, the positions (Raman shift) and line widths (FWHM) are independent of crystallite orientation. Because of this reason, Raman spectroscopy is considered a suitable technique for analyzing octocoral samples without polishing the surface skeleton. Polishing the surface skeleton would require removing sample material which would disrupt the connection between skeletal geochemistry and environmental to be measured at the time of octocoral sample collection.

The Mg content of the octocoral surface skeleton was calculated using the ν_1 peak calibration lines from Perrin et al. (2016). The calibration line for ν_1 Raman shift was

$$\text{Raman shift (cm}^{-1}) = 0.256 \times [MgCO_3 \text{ (mol\%)}] + 1085.71 \; (R^2 = 0.988, N = 20) \tag{S2}$$

which covers a range of 0 to 50 mol% $MgCO_3$. Overall ν_1 FWHM can be partitioned into a Mg-driven component (Mg-driven ν_1 FWHM) and a non-Mg component (residual ν_1 FWHM). Mg-driven ν_1 FWHM is calculated by applying the Mg content from the ν_1 Raman shift calibration line to the ν_1 FWHM calibration line:

$$\text{FWHM (cm}^{-1}) = -0.00787 \times [\text{MgCO}_3 \text{ (mol\%)}]^2 + 0.51 \times [\text{MgCO}_3 \text{ (mol\%)}] + 3.61$$

$$(R^2 = 0.973, N = 15) \qquad \text{(S3)}$$

Residual ν_1 FWHM is the difference between the overall ν_1 FWHM signal and Mg-driven ν_1 FWHM.

Since concentrations and variability of Mg in octocoral skeleton are notably greater than that of other seawater ions (e.g., Sr, Ba, B), observed changes in ν_1 Raman shift should be predominantly driven by incorporated Mg. For instance, octocoral Sr/Ca and B/Ca had ranges of only around 1.26 mmol/mol and 59 μmol/mol, respectively (Farmer et al. 2015; Vielzeuf et al. 2018). Using the ratios from Farfan et al. (2021), this translates to Raman shift decreases of 0.069 cm^{-1} and 0.023 cm^{-1}, which are small compared to the expected 1.67 cm^{-1} increase from Mg based on Mg/Ca ranges (~64 mmol/mol) from Vielzeuf et al. (2018). A similar outcome is reached with respect to FWHM for those ranges in Mg/Ca (+1.91 cm^{-1}), Sr/Ca (-0.047 cm^{-1}), and B/Ca (-0.018 cm^{-1}). Farfan et al. 2021 did not measure Ba/Ca, but its concentration in octocorals (range of 8.1 μmol/mol) is less than that of B/Ca (Vielzeuf et al. 2018).

EMPA measurement of octocoral cross section

High-resolution spatial patterns in Mg were measured within single cross section sample of Corallidae (species unknown, Taiwan). The octocoral cross section was first polished and coated with Pt-Pd before analysis. The two-dimensional distribution of Mg and Ca of the cross section was observed using an electron microprobe analyzer (JXA-8900, JOEL) at the Atmosphere and Ocean Research Institute, The University of Tokyo. The analysis was carried out with the following settings: 15 kV accelerating voltage; 200 nA probe current; 150 sec dwell time; and 10 μm probe diameter. The distribution of Mg/Ca count ratios was visualized using ImageJ software (NIH, USA).