Role of the Deglacial Buildup of the Great Barrier Reef for the Global Carbon Cycle

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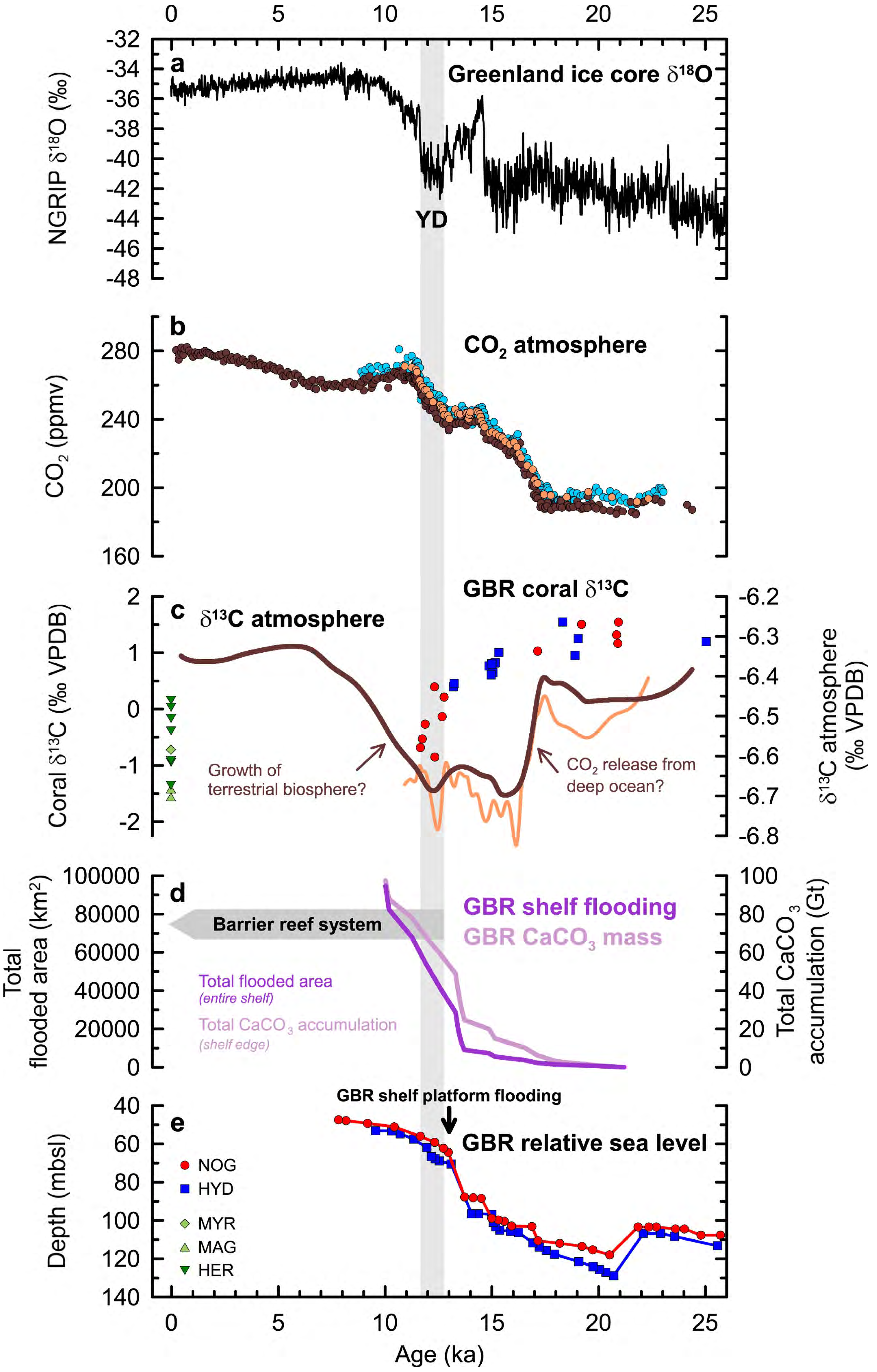
The carbon isotope ^{13}C is commonly used to attribute the last deglacial atmospheric CO_2 rise to various processes.

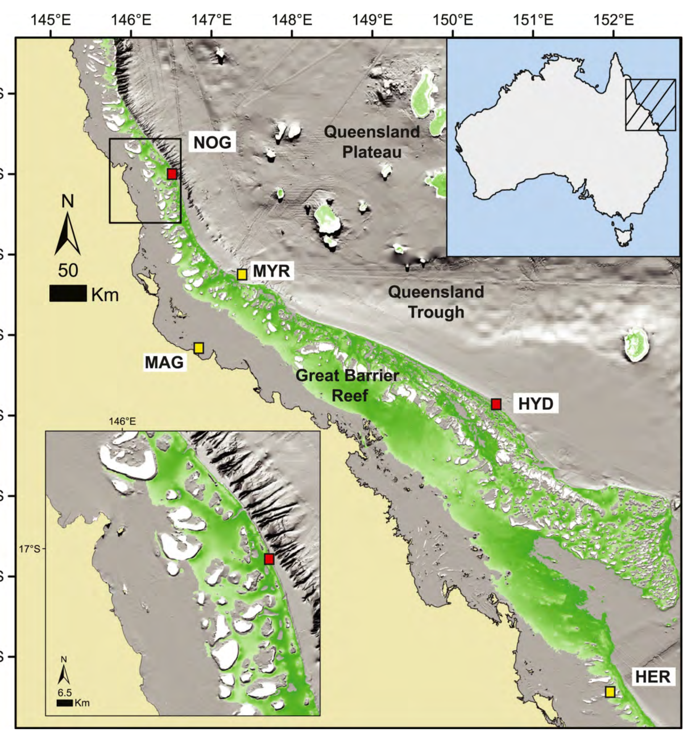
Here we show that the growth of the world's largest reef system, the Great Barrier Reef (GBR), is marked by a pronounced decrease in $\delta^{13}C$ in absolutely dated fossil coral skeletons between 12.8 and 11.7 ka, which coincides with a prominent minimum in atmospheric $\delta^{13}CO_2$ and the Younger Dryas.

The event follows the flooding of a large shelf platform and initiation of an extensive barrier reef system at 13 ka. Carbon cycle simulations show the coral $\delta^{13}C$ decrease was mainly caused by the combination of isotopic fractionation during reef carbonate production and the decomposition of organic land carbon on the newly flooded shallow-water platform.

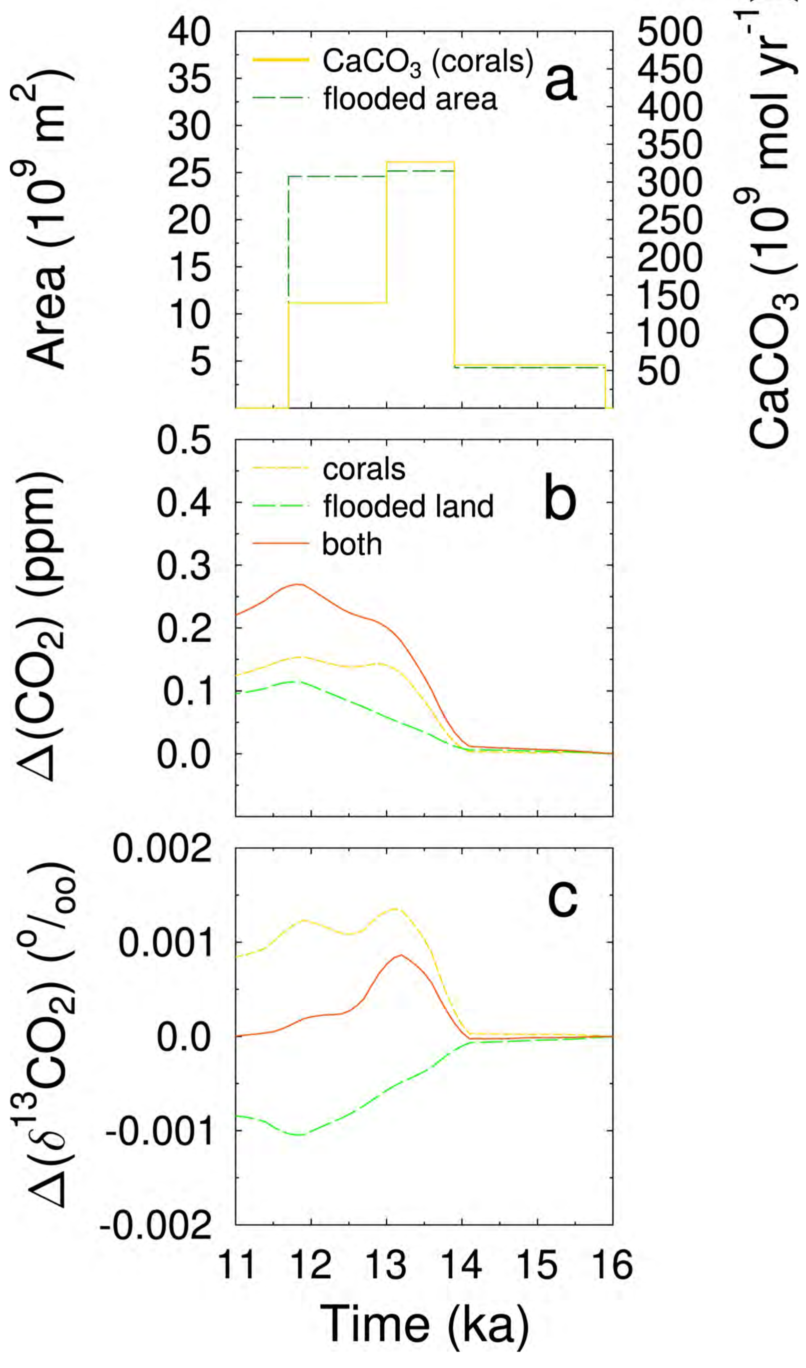
The impacts of these processes on atmospheric CO_2 and $\delta^{13}CO_2$, however, are marginal. Thus, the GBR was not contributing to the last deglacial $\delta^{13}CO_2$ minimum at ~12.4 ka.



Great Barrier Reef (GBR) coral $\delta^{13}C$, shelf flooding, carbonate accumulation, sea level records and ice core records of atmospheric carbon. **a** Greenland ice core $\delta^{18}O$ record (North Greenland Ice Core project, NGRIP) (North Greenland Ice Core Project members, 2004), Younger Dryas (YD) cold event indicated. **b** Antarctic ice core reconstructions of atmospheric CO_2 (dark brown (Schmitt et al., 2012), light blue (Marcott et al., 2014), light brown (Bauska et al., 2016)). **c** Antarctic ice core reconstructions of $\delta^{13}C$ of atmospheric CO_2 (dark brown (Schmitt et al., 2012), Monte Carlo average; light brown (Bauska et al., 2016), smoothing spline). Mean skeletal $\delta^{13}C$ of GBR shallow-water corals (Felis et al., 2014), anomalous 12.8 to 11.7 ka interval indicated (grey bar). Central GBR sites: Noggin Pass (NOG, red circle), Hydrographer's Passage (HYD, blue square), Myrmidon Reef (MYR, light green rhomb), Magnetic Island (MAG, light green triangle). Southern GBR site: Heron Island (HER, dark green triangle). **d** Calculated total (cumulative) marine-flooded area (Hinestrosa et al., 2019) (dark pink) at entire GBR shelf and reef carbonate ($CaCO_3$) accumulation (light pink) at shelf edge using sea level reconstructions (Webster et al., 2018; Yokoyama et al., 2018) from (**e**) (Text S1). **e** GBR maximum relative sea level reconstructions at NOG and HYD sites (Webster et al., 2018; Yokoyama et al., 2018). For uncertainties see original publications and Table S2 in Felis et al. (GRL 2022).

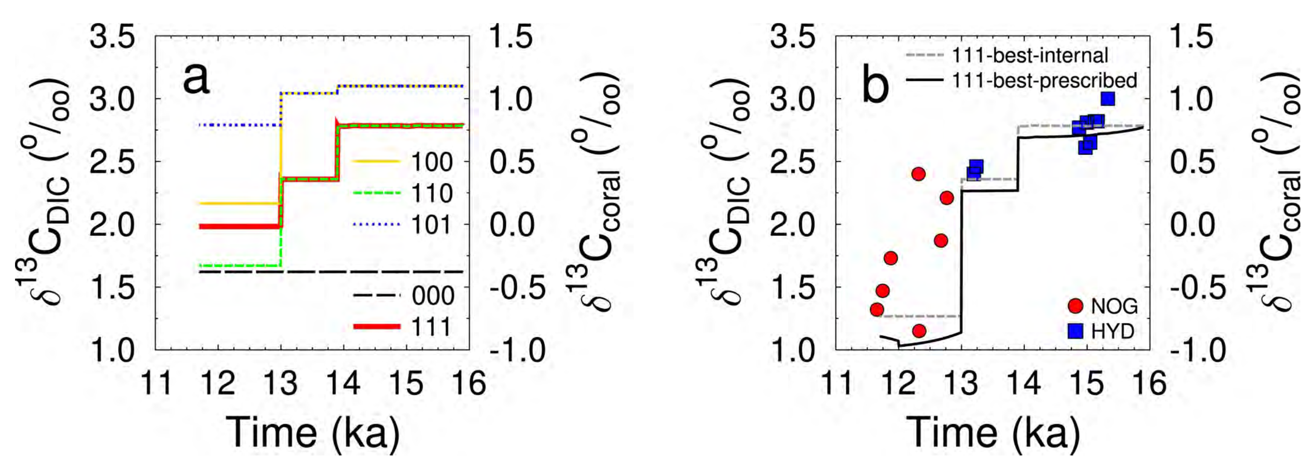


Map of the Great Barrier Reef (GBR) shelf. Flooded areas corresponding to sea levels between 45 m and 75 m below present indicated (green) on present-day GBR bathymetry (Beaman, 2010). 45-75 m depth band shows extent of flooded terrestrial areas following 13.0 ka shelf platform flooding encompassing maximum range (depth and time) at which growth of 'proto-GBR' (Reef 4) took place (Webster et al., 2018). Reef growth predominantly occurred along shelf edge seaward of modern GBR (Hinestrosa et al., 2019) (white areas). Not all flooded areas (green) were in situ reefs, but rather a variety of relatively shallow shelf settings. Locations of Integrated Ocean Drilling Program (IODP) Expedition 325 drilling sites at Noggin Pass (NOG) and Hydrographer's Passage (HYD) at central GBR shelf edge (Webster et al., 2011) (red squares). Modern coral sites at Heron Island (HER) (southern GBR) and Myrmidon Reef (MYR) and Magnetic Island (MAG) (central GBR) (yellow squares). Inset: Regional close-up of IODP site at NOG.



LEFT: Results of global carbon cycle model with implemented Great Barrier Reef (GBR) growth. The carbon cycle model BICYCLE (Köhler & Munhoven, 2020) was used for the simulations. **a** Model forcing by the prescribed flooding of GBR shelf area and of coral carbonate ($CaCO_3$) production. Changes in atmospheric (**b**) CO_2 and (**c**) $\delta^{13}CO_2$ following three scenarios: (1) the prescribed accumulation of GBR coral carbonate with an isotopic fractionation during carbonate production of -2‰; (2) shelf flooding and release of CO_2 with $\delta^{13}C$ = -21‰ from respired land carbon into the atmosphere assuming 30 kgC m^{-2} (15.9-13.0 ka) or 60 kgC m^{-2} (13.0-11.7 ka); (3) a combination of both.

BOTTOM: Contribution of different processes and best-guess results of 3-box carbon cycle model of Great Barrier Reef (GBR) growth. Simulated $\delta^{13}C$ values of seawater dissolved inorganic carbon (DIC) in GBR box, and of signal recorded by coral skeletons if an isotopic fractionation of -2‰ is assumed. **a** Scenarios follow a three-digit code showing 1 (on) or 0 (off), where the first digit states if coral carbonate accumulation, second digit if land carbon release after shelf flooding, and the third digit if changes in the water mixing between GBR box and open ocean at 13.0 ka is considered. **b** Two scenarios (prescribed versus internally calculated atmospheric $\delta^{13}CO_2$) are shown with optimized (best-guess) parametrization (the amount of respired land carbon on flooded shelf assumed to raise from 30 kgC m^{-2} to 60 kgC m^{-2} at 13.0 ka). In the prescribed scenario, atmospheric $\delta^{13}CO_2$ is fixed for 15.9-13.0, 13.0-12.0, 12.0-11.7 ka at -6.6, -6.8, -6.6‰ following maximum amplitudes in Antarctic ice cores (Bauska et al., 2016), while in the internal scenario atmospheric $\delta^{13}CO_2$ is internally calculated in the model. For comparison, Integrated Ocean Drilling Program Expedition 325 GBR coral $\delta^{13}C$ data from Noggin Pass (NOG) and Hydrographer's Passage (HYD) are shown (Felis et al., 2014).



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Exp. 325 - Great Barrier Reef Environmental Changes

Citation:
Felis, T., Hinestrosa, G., Köhler, P., & Webster, J. M. (**2022**).
Role of the deglacial buildup of the Great Barrier Reef for the global carbon cycle.
Geophysical Research Letters, *49*, e2021GL096495. https://doi.org/10.1029/2021GL096495

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