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2B Coral reefs: is the past the key to the future?

Can Flooding Rainfall Events Be Revealed In Oceanic Coral Cores?

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Abstract. The oceanic setting of Coral Sea reefs and cays provide a fantastic habitat to investigate chemical and isotopic interpretative records such as temperature, salinity and nutrients without the blurring effect of terrestrial influence. Through the use of now-standard palaeoclimatological techniques on samples from Coral Sea reefs, it is hoped that it will be possible to evaluate the practicability of using deep sea reefs as interpreters of past climate conditions in other regions. Specifically, cores of large *Porites sp*. can be geochemically analysed for freshwater anomalies, thus acting as proxy rainfall records and potentially informing on climate records onshore. The Coral Sea represents a significant source for onshore tropical rains in the form of low pressure systems and cyclones that bring flooding rains to the east coast of Australia. These systems often pass southwards along the coastline, and penetrate inland where they introduce flooding rains to the inland. Long term records of these systems within coral cores from Coral Sea reefs and cays could provide more robust statistical characterisations of flooding rain events such as those witnessed in the past few years. Samples obtained from Flora and the Holmes reefs in the Coral Sea revealed bright UV luminescent anomalies associated with Cyclone Rona, suggesting that these proxies are viable tools for analysis of past flooding rainfall events.

Key words: Coral Cores, Extreme Rainfall, Floods.

Introduction

In 2008, flooding from high intensity rainfall in upper catchments of the Nogoa River system paralysed the mining industry in the Central Highlands. In 2010/2011 similar rainfall patterns were experienced in Queensland, New South Wales, Victoria, South Australia and the Northern Territory, with flooding covered the majority of eastern Australia.

Typically, wet season rains within the seasonally arid tropics (Fig. 1) fall as intense bursts in small, isolated cells, often little more than kilometres apart. These cells move slowly across a landscape to deliver enormous quantities of rainfall to multiple tributaries of the same river system. Rainfall intensities of 190 mm in 72 hours are common, often followed by similar amounts within days. Rainfall cells can sit over a catchment for days before drifting to the next catchment leading to large totals within individual systems and severe flooding.

Within the seasonally arid tropics of Queensland, rainfall patterns follow either the southward migration of the Inter-Tropical Front (the Monsoons) and/or the development of cyclonic activity. A study of cyclone tracks and associated rainfall patterns from the Bureau of Meteorology (BOM) (Gillespie 2011) reveal that all cyclones that cross the coast of Queensland affect the Central Queensland district to some degree. Gillespie (2011) found however, that cyclones crossing the northeast Queensland coast after originating in the Coral Sea have the largest overall impact on rainfall patterns throughout the state.

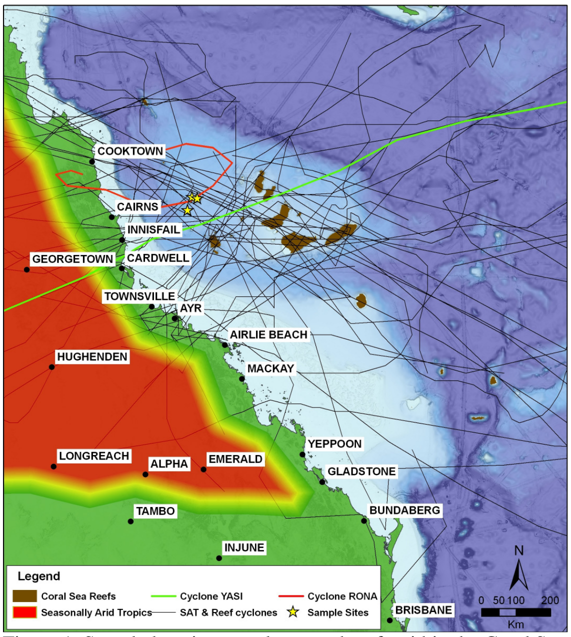

Figure 1: Sample locations, cyclones and reefs within the Coral Sea

The flooding rains of Cyclone Yasi in 2011 for example, dominated the state's weather patterns for weeks following the event.

The structure and composition of a coral's aragonite skeleton provides a surrogate record of the environmental conditions in which the coral has grown. Due to the longevity of massive corals, many different palaeoclimatic tracers within the skeletal matrix of these corals are used to evaluate past climates (Felis and Patzold 2003). Coral skeletons display a series of luminescent bands when examined under ultraviolet illumination, and the occurrence and intensity of these bands has been recognised as a proxy for freshwater influence on the environment within which the corals grow (Isdale 1984). Isdale (1984) suggested that these bands could be used to reconstruct the record of coastal runoff from historic river flow plumes. They have also been suggested for use as a record of coastal rainfall (Lough 2011). Lough (2011) further suggests that this proxy can be used to reconstruct past rainfall events thereby extending the instrumental records of past tropical climate variability considerably. It is important to note, however that the locations of the samples from which these coral proxies are taken are critical to the conclusion drawn from the data.

Material and Methods

Various methods of coral luminescence measurement have been tested and used within the literature. Isdale (1984) illuminated coral slices with a UV light and recorded their luminescence on a spectrofluorometer. Boto and Isdale (1985) used a mercury lamp with a 360 nm band pass filter as a light source and an atomic adsorption spectrophotometer to measure coral luminescence. Other authors have used lasers of varying bandwidth as light sources; 266 nm (Peng et al. 2002), 337 nm (Milne and Swart 1994) and 3 pairs of both excitation and emission wavelength 310/430, 425/480 and 390/530 nm (Nyberg 2002). Each of these studies used differing detection methods for measurement of the luminescence; emitted light being filtered onto a photomultiplier (Peng et al. 2002), the emitted light being passed through a monochromators and measured via a UV-enhanced silicon photocell (Milne and Swart 1994) and a spectrofluorometer with attached scanning chromatography plates (Nyberg 2002). Despite these differing techniques, Lough (2011) concluded that both visual inspection of coral luminescence and measured indices could provide similar records of freshwater occurrence and relative intensity. Following Lough's findings, for the purposes of this study, a visual analysis of corals under ultraviolet light was conducted.

In October 2010, seven samples of *Porites lutea?* were obtained from the Flora Reef, East Holmes Reef and West Holmes Reef 190 – 220 km offshore (115-150 km past the shelf edge) in the Coral Sea (Fig. 1) (Bongaerts et al. 2011). These samples consist of 45 mm cores ranging from 6 to 13 cm in length, taken from live coral communities at depths from 11 m to 32 m. It is important to note that during the research cruise, the shallow reef areas of the sampling sites (<30 m) revealed very low coral cover with predominantly juvenile corals. This necessitated that samples be taken from small communities with short records. It also revealed the effect of large cyclones on offshore reef systems, largely denuding the reef base of full coral cover.

The seven samples were all halved longitudinally, and a 2 mm slice was taken from the centre of each core. These slices were viewed and photographed under an ultraviolet light (Fig. 2).

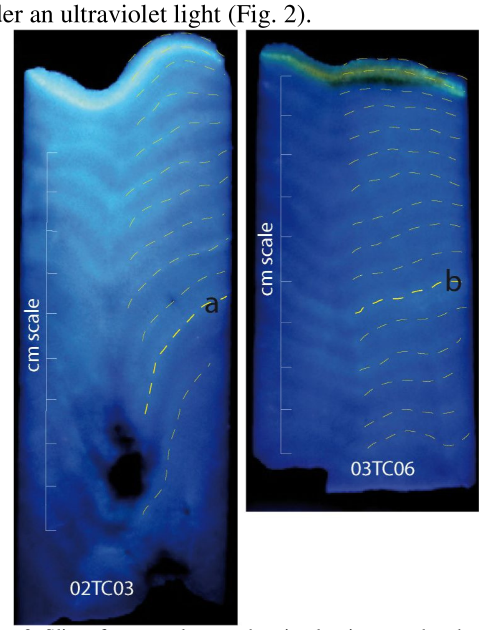

Figure 2: Slices from coral cores showing luminescent bands marked with dashed yellow lines with prominent bright bands marked"a" and "b"

Results

Analysis of the coral core slices under UV light revealed that four of the seven samples (01TC01, 02TC03, 03TC05 and 03TC06) exhibited clear luminescent bands. Additionally, two of the cores that do not exhibit luminescent banding (02TC04 and 03TC07) show clear annual growth bands within their aragonite skeletons under white light that were overprinted by sediment or algal staining.

Three samples show a more prominent bright band half way down each core (Fig. 2) which for each of the three samples counts as the eleventh band from the live surface of the core. Eleven years prior to sample collection in October 2010 corresponds with the wet-season of 1998/1999, when Cyclone Rona

(System au199899_09u) passed directly over the Holmes Reefs (Fig. 1).

Discussion

Thus far, studies of luminescent coral banding as a proxy for freshwater influence within Queensland have largely been restricted to the coastal riverine flows within the Great Barrier Reef (Isdale et al. 1998; Lough et al. 2002; Hendy et al. 2003; Lough 2007). By utilising the same techniques for coral communities on reefs and cays within the distal Coral Sea, riverine and other terrestrial influence can be discounted. In this way, freshwater anomalies within the coral communities are most likely associated with rainfall from major tropical storm cells such as cyclones. Lough showed that the distance off-shore across the GBR shelf was inversely related to the visual luminescence indices of coral cores (Lough et al. 2002; Lough 2011). Despite this, the cores retrieved from the Holmes and Flora reefs show distinct luminescent banding that could be attributed to freshwater input in the offshore reef system. The bright luminescent band that corresponds with cyclone Rona indicate that this proxy is a valid tool for recognition of past large rainfall events offshore, distal of riverine and onshore influence. The three samples that record this prominent luminescent band were collected from 10.2, 10.4 and 17 m depth, indicating that the freshwater rainfall plume from a cell such as cyclone Rona has an influence within the top 20 m of the water column. This suggests that as a proxy, samples collected down to a depth of 20 m should be applicable.

As outlined in the Introduction, various tracers within coral geochemistry can be used as tracers of the chemistry of oceanic waters within which the corals developed, Tracers used include δO18 (Gagan et al. 1994) and Sr/Ca ratios (Beck et al. 1992) that when combined, can be used to reconstruct variations in the hydrological balance due to evaporation or precipitation (McCulloch et al. 1994; Gagan et al. 1998). Whilst these proxies and surrogate measurements are easily blurred by proximity to the mainland influence in the form of riverine runoff and resultant freshwater plumes, when used on offshore reefs, they could provide further evidence for or against the use or luminescent bands as a tracking method of cyclones and rainfall cells. It is important to note that whilst visual analysis methods were used in this study, any analysis of coral cores in order to add to historic rainfall records would require quantitative methods such as those identified within the Methods section above. Further comparative analysis of these methods may prove useful to define an index for these types of records.

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