Corals track past Hurricanes

The strong hurricane activity observed during the last decade fuelled the debate whether global warming is a major force. The crux of the recent debate is the limited length of the reliable instrumental record that exacerbates the detection of possible long-term changes in hurricane activity, which naturally exhibits strong multidecadal variations in association with the Atlantic Multidecadal Oscillation (AMO). We analysed the stable oxygen ($\delta^{18}O$) of a Caribbean brain coral which records both hurricane activity and AMO. This proxy record is equally sensitive to variations in sea surface temperature (SST) and seawater $\delta^{18}O$, with the latter being strongly linked to precipitation and evaporation. The SST and precipitation signals in the coral provide the longest continuous proxy-based record of hurricane activity that interestingly exhibits a long-term increase over the last century.

Massive shallow water corals, characterized by annual density bands, in which seasonally changing environmental signals are incorporated as geochemical traces are well known climate and paleoclimate recorders. The development of *Diploria strigosa* as a reliable archive (Hetzinger et al. 2006) for Tropical Atlantic climate provided the base for this study. Proxies derived from corals so far are biased by variations in growth and skeletal microarchitecture. In December 2004, we drilled a 1.15m coral core from such a hemispherical colony growing in a water depth of 2m in the fringing reef near Cayo Sal (11.77°N, 66.75°W), at the southernmost rim of the Los Rocques archipelago. Micro-samples for oxygen isotope analysis were retrieved in 1mm increments yielding approximately monthly resolution. The monthly $\delta^{18}O$ record extends from 1918 to 2004.

Year-to-year variations in coral $\delta^{18}O$ (Fig. 1A) are significantly correlated with SST at the study site. Both coral $\delta^{18}O$ and SST show pronounced multidecadal variations with a period of ~60 yr (Fig. 1B). However, the magnitude of the multidecadal variations in coral

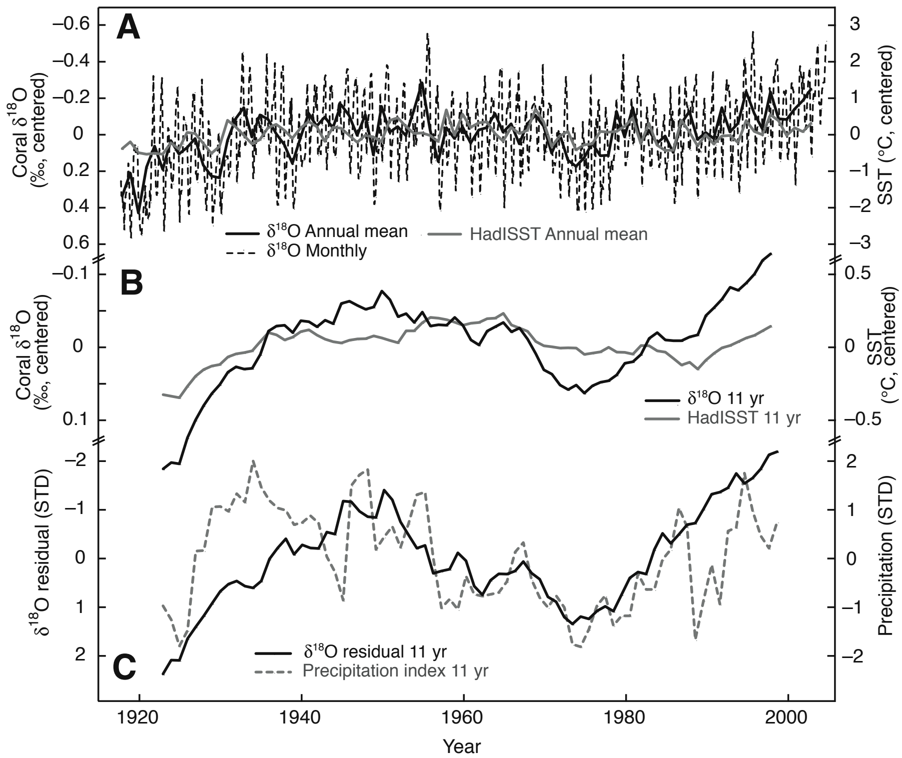

Figure 1: Coral $\delta^{18}O$ chronology and climate parameters. A: Monthly and annual mean oxygen isotopes ($\delta^{18}O$) from the Los Roques coral core compared to annual mean (gridded) SST (HadISSTv.1.1) at the study site (12°N, 66°W). Coral $\delta^{18}O$ and local SST data are negatively correlated ($r = -0.58$ for annual means). The correlation is significant at the 1% level, assuming 83 degrees of freedom.
B: Comparison between coral $\delta^{18}O$ and SST averaged using an 11 yr running filter. The correlation amounts to $r = -0.69$ for the period 1923–1998. Data in A and B were centred by subtracting the mean and scaled so that −0.2‰ $\delta^{18}O$ corresponds to 1 °C.

$\delta^{18}O$ is larger than expected based on SST alone. Subtracting the SST component from the $\delta^{18}O$ of the coral provides the $\delta^{18}O$ residual, a measure of $\delta^{18}O_{seawater}$ which portrays precipitation.

Low-frequency SST variability in the tropical North Atlantic influences the intensity of hurricanes. Los Roques coral $\delta^{18}O$ correlates well with large-scale SST variations in the tropical North Atlantic, especially SST in the south-central part, the main hurricane development region, making this site ideal for detecting past changes in hurricane activity. Vertical wind shear is another important factor controlling hurricane activity (Latif et al. 2007), which is controlled not only by local but also by SST outside the Atlantic. The coral $\delta^{18}O$ correlates also well with multidecadal fluctuations in vertical wind shear. The two are related because the latter are associated with meridional displacements of the Inter-Tropical Convergence Zone (ITCZ). The coral, due to its position, records shifts in the ITCZ through the variations in precipitation. Recording both SST and vertical wind shear, the coral $\delta^{18}O$ variability is an excellent proxy to infer past changes in hurricane activity.

We compared directly the coral $\delta^{18}O$ record with the index of Accumulated Cyclone Energy (ACE), a measure of hurricane activity that takes into account the number, strength, and duration of all tropical storms in a season and which shows pronounced multidecadal variability. Since the typical hurricane peak season is from August to October we selected the corresponding $\delta^{18}O$ data from the coral record and applied an ordinary least squares regression analysis. A strong and statistically significant relationship exists between seasonal mean August-September-October averaged coral $\delta^{18}O$ and the ACE index (Fig. 2A;

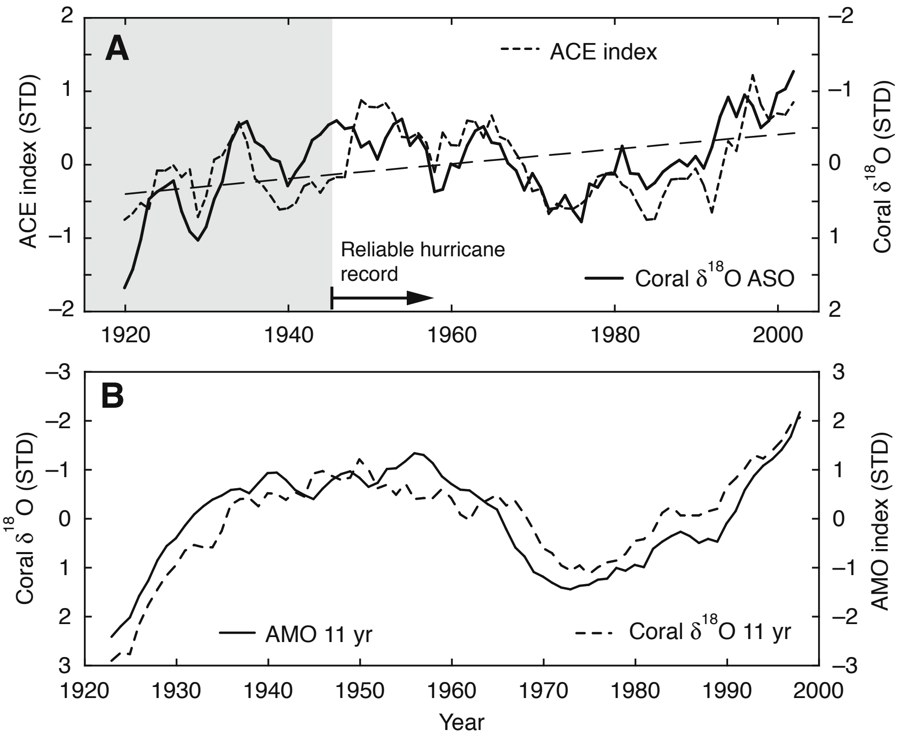

Figure 2: A: Comparison between coral $\delta^{18}O$ and the index of Accumulated Cyclone Energy (ACE) for the North Atlantic. Data shown are for the peak months of the Atlantic hurricane season, August-September-October (ASO), and were averaged using a 5 yr running filter. The correlation is high (r = –0.66) and significant at the 1% level, assuming 14 degrees of freedom (1920–2002); r = –0.52 for unsmoothed ASO data (not shown), 1918–2004. The correlation is also stable for de-trended values (r = –0.50 for unsmoothed ASO data; and r = –0.67 for 5 yr means, same time intervals as above). Dashed line represents the upward trend seen in coral $\delta^{18}O$ during1920–2002. The trend is statistically significant at the 0.1% level, assuming nine degrees of freedom.
B: Comparison between coral $\delta^{18}O$ and the AMO index (North Atlantic SST averaged between 0 and 70°N; Enfield et al., 2001). Seasonal mean values were removed from the monthly data before averaging to annual resolution. An 11 yr running filter was subsequently applied. The correlation is high (r = –0.86) and statistically significant at the 5% level, even with only four effective degrees of freedom. AMO: Atlantic Multidecadal Oscillation; ASO: August-September-October; STD: standard deviation.

r = -0.66; 1920–2002). A comparison with the so-called "power dissipation index", another commonly used hurricane index, revealed similar results. The coral proxy record is a particularly good indicator of decadal to multidecadal swings in the ACE index (Fig. 2A). The relationship to the ACE index is equal to or even better than the relationship between SST and ACE. This is due to the changes in vertical wind shear that are additionally recorded by the coral. In summary our results demonstrate that coral-derived proxy data can be used to reconstruct changes in hurricane activity well beyond the reliable instrumental record beginning in the 1940s with the regular aircraft measurements.

Figure 2A additionally shows a clear and statistically significant negative trend in the coral $\delta^{18}O$ record that is superimposed on the pronounced decadal to multidecadal variability. The trend in the coral $\delta^{18}O$ indicates a significant warming and/or freshening of surface waters in the region of tropical cyclone formation. This indicates a slow increase in hurricane activity over the last century. Such an increase may be expected in response to global warming. However, longer coral records are needed in the presence of strong multidecadal variability to reliably detect a potential anthropogenic impact on hurricane activity.

Furthermore, a close relationship between the decadal to multidecadal variability in the coral $\delta^{18}O$ and the Atlantic Multidecadal Oscillation (AMO) is found (Fig. 2B). The AMO is the major mode of low-frequency climate variability in the North Atlantic Ocean. Despite the fundamental importance of the AMO for Northern Hemisphere climate, most available reconstructions of the AMO are solely based on continental proxies with annual or even lower resolution. So far, coral proxies have failed to show a clear AMO signature. However, our coral data exhibit a strong and statistically significant correlation (r=-0.86) with the smoothed AMO index (Fig. 2B). Both SST and in rainfall in the southeastern Caribbean are driven by the AMO, so that our coral $\delta^{18}O$ index provides an excellent recorder of it.

As *Diploria strigosa* coral colonies are abundant throughout the entire Caribbean and Western Atlantic region and can live up to several hundred years, we are confident that corals of this species will become an important new marine high resolution archive that can be used in future studies to reconstruct ACE and AMO variability beyond the instrumental record.

References

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