Coral Climate History of the Subtropical North Atlantic (CorClim)

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Introduction

There are only a few high-resolution proxy records of North Atlantic climate variability and associated teleconnection patterns (e.g. Kuhnert et al., 2002). The generation of additional data that extend beyond the period of instrumental measurements at key locations is essential to improve climate reconstructions. Bermuda represents such a key location. The region is sensitive to North Atlantic Oscillation (NAO) variability, where the NAO influence is exerted by local air-sea interactions as well as by large-scale changes in the circulations of the Gulf Stream and the North Atlantic Subtropical Gyre. Bermuda also represents the northernmost site in the Atlantic Ocean where climate records can be recovered from stony reef corals.

Here we investigate two coral specimens (*Montastrea cavernosa, Diploria strigosa*) from Bermuda, collected at the same site and depth (12m). The data include monthly Sr/Ca ratios from *Diploria* and annual skeletal growth rates from both species, extending back from 1983 to 1929 and 1842, respectively. Therefore, instrumental as well as pre-instrumental times are represented by the corals, which makes it possible to calibrate against instrumental data.

Coral Records

Sr/Ca ratios in coral skeletons are usually considered a function of water temperature, with seawater Sr/Ca and metabolic effects as secondary modifiers. In the Bermuda coral, seasonal changes in Sr/Ca are attributable to the temperature cycle. However, our results suggest that sea surface temperature (SST) is not the dominant forcing factor on the interannual timescale. When time series of quarterly averages are calculated from the Sr/Ca record, the October-December averages are correlated with the winter NAO index (r=-0.50; Fig. 1), at a lag of almost one year. This lag is similar to the response time of the Subtropical Gyre and Gulf Stream circulations to NAO forcing (e.g., Curry and McCartney, 2001), which hints at potential changes in the local water mass composition driving the Sr/Ca signal. The coral record shows a subdecadal variability (7.5-year cycle) that compares well with that of the NAO index, while the long-term trend (e.g. the decrease from the 1940s to the 1960s) is more pronounced in the proxy data.

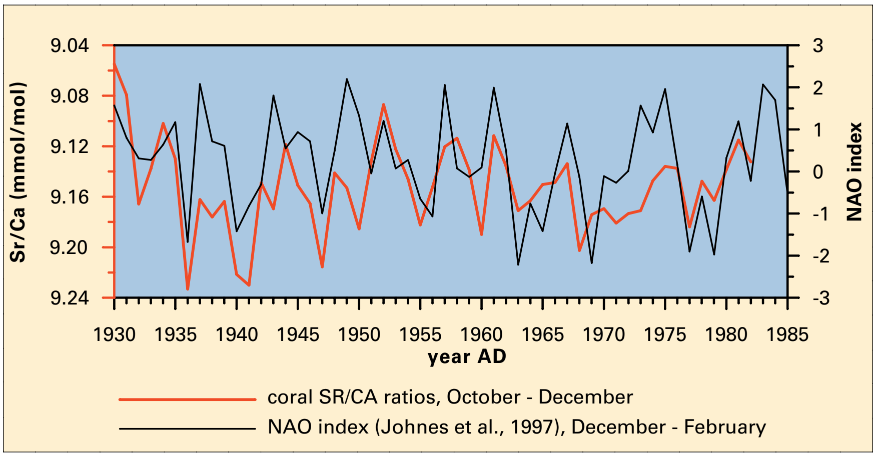

Fig. 1: Comparison of October-December (OND) coral Sr/Ca ratios (bold red line) and the December-February (DJF) NAO index (thin black line; Jones et al., 1997). The correlation coefficient is -0.50 for the time period 1928 to 1982. The axis for Sr/Ca is reversed for better comparison.

Coral skeletal growth at Bermuda is anti-correlated with temperature. The relationship is indirect: in cooler years, vertical mixing of the water column is more intense and the corals benefit from raised levels of inorganic and planktonic food. Spectral analyses indicate that coral growth primarily responds to SST variability on decadal to multidecadal timescales.

Upscaling Model for Sargasso Sea SST

The relationship between coral data and SST can be used to reconstruct SST fields. In order to develop such an upscaling model, the two growth rates for the period 1902-1983 were used. To find the common climate-driven signal for both time series, Empirical Orthogonal Functions (EOFs) were developed from the normalized growth rates. The first EOF explains about two-thirds of the variance of the time series.

The correlation map of the temporally smoothed first principal component (PC1) of the growth rates and the annual mean SSTs (Kaplan, et al., 1998) is shown in Fig. 2. Negative correlations are found for Bermuda, the surrounding Sargasso Sea, and the northern adjacent areas. The correlation values around Bermuda for PC1 are higher and the correlation patterns for different periods more stable than for the single coral chronologies. Therefore, PC1 is more suitable than the raw growth rate data for use in upscaling models.

We developed an upscaling model for the Sargasso Sea SST using a linear regression between the coral PC1 and SSTs. The area of the SST field that is represented by the corals covers 15° in the latitudinal and 20° in the longitudinal direction (Fig. 2). The SST regression pattern resembles the correlation pattern in this area: it is characterized by a gradient with negative anomalies over the largest parts of the area and small positive anomalies near the southeastern border. Cross-validation of the model leads to a correlation coefficient of 0.54 between coral time series and the series obtained from the projection of the

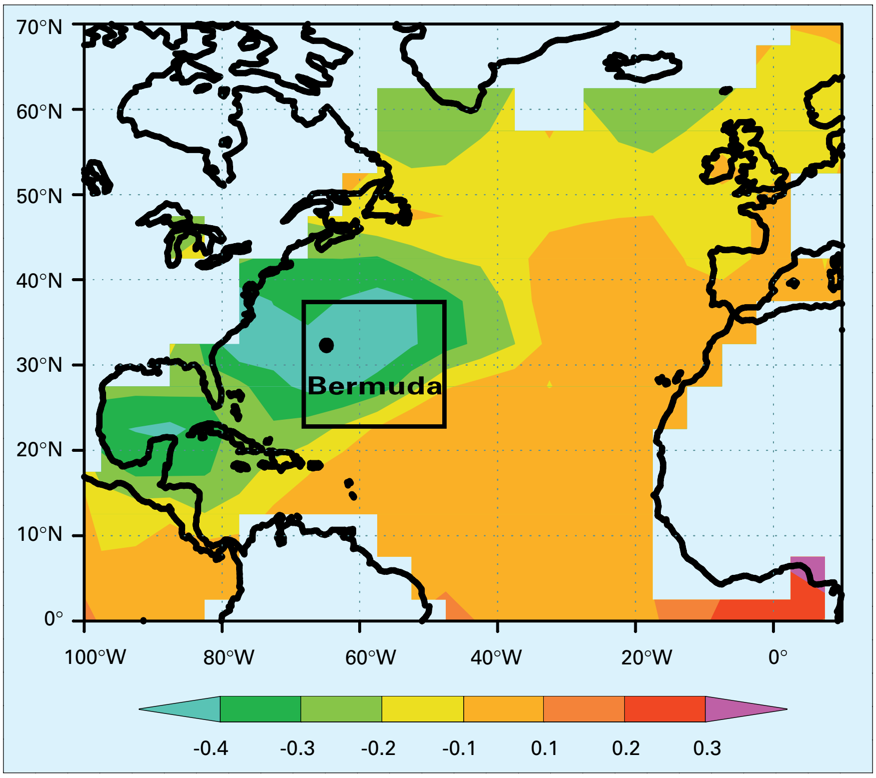

Fig. 2: Correlation between annual SSTs and PC1 of coral growth rates (1902-1983), smoothed with a 3-year running mean and detrended. The square defines the spatial extension of the upscaling model.

real SST fields onto the regression pattern. Thus, the coral growth rates explain about 30% of the variability of the SST field.

Outlook

Correlation between coral PC1 and northern-hemispheric sea-level pressure (SLP) resembles the NAO pattern (not shown here). These large-scale SLP field reconstructions for pre-instrumental times will be used to force a General Circulation Model (GCM) with the DATUN technique, enabling the validation and improvement of the GCM, which in turn will increase the reliability of future climate scenarios.

While the primary goal of the project is the reconstruction of more recent climate variability, the methodological approach is also largely applicable to the Holocene and last interglacial times, and this has been demonstrated in the collaboration with the DEKLIM-Cli-Trans project (Felis et al., 2004).

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