GLOMAR

Doctoral Colloquium

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160 years oceanic variability of the Gulf of Mexico reconstructed from A S. siderastrea coral core

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Instrumental in-situ observations of climate and environmental parameter changes are sparse and only date back until the mid 20th century for the most part. Multidecadal variability cannot be well reflected in a short record like this. To truly separate the anthropogenic impact from natural variability in the climate system, longer time series, giving us a basis to go off of, are needed. Only then can we evaluate the impact of ongoing environmental changes in the ocean on marine organisms.

Climate sensitive proxies have been largely used on land and in the ocean to extend the environmental record beyond the instrumental one. One organism group that incorporates the environmental information of the ocean into its skeleton are massive tropical corals. Their extension rate of a few millimeters to centimeters per year makes it possible to retrieve ultra-high resolution of sub-seasonal records. Trace elements and stable isotope measurements can reveal changes in sea surface temperature (SST), sea surface salinity (SSS), and the carbonate chemistry of the ocean. The latter has so far been largely restricted to the reconstruction of pH from corals. While there are a few studies on the northern Gulf of Mexico (GOM) in the Atlantic, the southern part has been mostly neglected for SST, SSS, and carbonate chemistry reconstructions. For each proxy reconstruction, a species-specific calibration is need, which is however mostly constricted to the Porites species that are common in the Pacific, but not frequently used in the Atlantic. Additionally, in-situ measurements for such calibrations are sparse, and coverage is less extensive in this region.

The objective of this thesis is to test whether the coral core taken from the northern Cuban coast is recording environmental changes in its skeletal material reliably and whether reconstructions of carbonate chemistry of seawater parameters can be based on coral skeletal materials. Furthermore, this thesis aims to establish a new species-specific pH- δ11B calibration for the coral Orbicella annularis, taken from La Parguera, Puerto Rico, and looks at the impact of secondary diagenesis on pH reconstructions.

For these purposes a multi-proxy record from a Siderastrea siderea coral core was generated for the southern GOM. The coral records show seasonal cycles that agree well with gridded SST. Oxygen isotopes, Sr/Ca and Sr-U as SST proxies present an increase in temperature over 160 years, spanning from 1845 to 2005. In the late 1980s, all proxies show a stagnation in the warming trend that can be linked to the decreasing strength of the Loop Current (LC), passing though the GOM. This trend is confirmed by coral cores in the northern GOM, that show a potential slow-down of the LC. Reconstructing δ18O of seawater (δ18OSW) makes it possible to gain insights into the hydroclimatology of the southern GOM. Although seasonal variabilities are not picked up by the δ18OSW signal, long terms trends such as the Atlantic Multidecadal Oscillation (AMO) pattern and the teleconnection between the Atlantic and Pacific are reflected in the data. Several El Niño years can be identified in the δ18OSW record as years of very low salinity. A shift to lower salinity values as a long-term trend in the 1980s indicates a shift in the AMO phase, from a negative to a positive one.

IAs the coral is recording changes in SST and SSS, it is also presenting variability in pH and other carbonate chemistry parameters. The coral recovered from Cuba shows a clear decline in pH in its extracellular calcification center (ECM) and the values reconstructed for seawater (SW). While total alkalinity (TA) is constant in SW, dissolved inorganic carbon (DIC) are increasing over time, which marks the carbonate chemistry of ocean acidification (OA). Simultaneously, in the ECM TA and DIC are decreasing. Although, the S. siderea coral is known to have a high temperature and low pH threshold the carbonate chemistry of the ECM indicates an already suffering coral, by showing a declining aragonite saturation state, and decreasing DIC and TA in its ECM.

Ongoing OA makes corals vulnerable to macro- and microboring organisms, thereby changing the geochemical signal extracted from the coral skeletal material to reconstruct environmental changes. An ultra-high resolution record was generated for the Caribbean coral Orbicella annularis with Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS), from Puerto Rico, to compare to high resolution in-situ measurements from a buoy nearby between 2014 and 2020. The record shows seasonal cycles in pH with a significant change to higher pH values after 2015. Secondary aragonite in boreholes from different organisms of the corals microbiome might be responsible for a shift to higher pH values. Fungi, cyanobacteria, and green algae infested the coral and have bored through the skeletal material. Secondary aragonite was able to precipitate in the empty boreholes and the LA method picked up the changes in the signal. The pristine material prior to 2015 yielded a species-specific pH-$\delta^{11}B$ calibration.

In summary, different coral records presented in this thesis capture climate variabilities in the wider Caribbean and are a valuable tool for extending the instrumental record further to the past.