Reconstructing Climate and Environment from Coral Archives

Tropical Coral Archives—Reconstructions of Climate and Environment Beyond the Instrumental Record at Society-Relevant Timescales; Bremen, Germany, 28 September 2017

A coral reef in the northern Red Sea has massive Porites colonies that are often used in paleoclimate research. At a workshop last fall, scientists met to foster a more coordinated approach to coral paleoclimate research. Credit: Thomas Felis, MARUM

By Jens Zinke, Miriam Pfeiffer, and Thomas Felis © 9 April 2018

The tropics are a region of heat gain for the globe: Tropical ocean sea surface temperatures influence atmospheric circulation, which redistributes heat and moisture from the tropics around the world. Warm-water currents such as the Gulf Stream, Kuroshio, and Agulhas carry excess heat from the tropics to higher latitudes (Figure 1).
Fig. 1. Atmospheric and ocean circulation transports excess heat from the tropics toward higher latitudes. This map of global sea surface temperature was produced using daily Moderate Resolution Imaging Spectroradiometer (MODIS) data. Red indicates warmer surface temperatures, yellows and greens are intermediate values, and blue indicates cold water. Most reef-building corals grow in tropical waters, delineated here by a solid black line. White boxes show the major climate phenomena in each ocean basin, brown arrows show the resulting ocean-atmosphere-land interactions, and white arrows show major ocean currents. Abbreviations are ENSO, El Niño–Southern Oscillation; PDO, Pacific Decadal Oscillation; NAO, North Atlantic Oscillation; AMO, Atlantic Multidecadal Oscillation; IOD, Indian Ocean Dipole; ITF, Indonesian Throughflow; ITCZ, Intertropical Convergence Zone; and SPCZ, South Pacific Convergence Zone.

Despite their importance, however, the extent of past climate fluctuations in the tropical oceans is still poorly understood. To bridge the knowledge gap, shallow-water corals have emerged as crucial climate archives. The data they provide cover long periods before the start of instrumental observations, and the study of these corals is known as coral paleoclimatology.

Last September, 34 experts from seven countries (Germany, Japan, the United States, Switzerland, Brazil, Indonesia, and Austria) gathered for a 1-day workshop at the MARUM—Center for Marine Environmental Sciences as part of the international conference GeoBremen 2017. The scientists, including 11 early-career scientists, represented such various disciplines as geochemistry, paleoclimatology, geochronology, statistics, climate dynamics, and coral ecology. The workshop was convened to build on the momentum of the successful Future Earth Past Global Changes (PAGES 2k...
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Tropical corals offer a precise reconstruction of marine climates and environmental change on a monthly timescale. Corals are a key archive for understanding variability over seasons, years, and decades, the timescales most relevant to human societies (Figure 2). Coral reconstructions extending back centuries provide a link between the period of instrumental observations of the past 50–150 years and coarse geological archives that do not relate to human scales.

These reconstructions are highly relevant when comparing ocean data with model simulations of global and regional climate change. Fossil corals provide snapshots of past seasonality and year-to-year change during glacial-interglacial cycles and across millions of years stretching from the Holocene, through the Pliocene, and into the Miocene (Figure 3).

Discussions at the workshop focused on identifying key scientific priorities for the coming decades and promoting future joint research activities to understand the long-term impacts of future changes.

on tropical oceans and reef ecosystems. Participants reviewed the motivations for the new PAGES CoralHydro2k project, temperature estimates from a variety of geochemical proxies and their uncertainties, the challenges with fossil corals, novel proxies for global biogeochemical cycles, and data management and sample exchange.

The workshop emphasized the unique opportunity of coral paleoclimatology to foster collaborations between various disciplines. The group highlighted the added value of measuring paired coral strontium/calcium ratios (Sr/Ca) and oxygen isotope ratios (δ18O), two key proxies for sea surface temperature that are often referred to as paleothermometers (https://eos.org/articles/climate-warming-may-have-helped-kill-the-dinosaurs) (δ18O also reflects sea surface salinity). Pairing these records enables scientists to infer past hydroclimatic variations (https://www.clim-past.net/13/1851/2017/) under changing climatic states like the industrial period, the Little Ice Age, and the Last Interglacial.

Two divers drill into a giant Porites colony off Madagascar. The coral cores are used to research past climate and environmental change. Credit: Jens Zinke, Freie Universität Berlin

Attendees also discussed complicated problems, including hydroclimatic responses to situations where anomalous events like the 2015–2016 El Niño are superimposed onto long-term heterogeneous ocean-warming patterns. Although these concomitant situations severely affect human societies, at present they are difficult to predict.

Workshop participants made several suggestions on how to further strengthen multinational collaborations, including the following:

extend a call for participation in PAGES CoralHydro2k (http://pastglobalchanges.org/ini/wg/2k-network/projects/coral-hydro) to analyze new paired Sr/Ca and δ18O records from key locations of the tropical oceans on various timescales
begin extended in situ monitoring to capture reef-scale sea surface temperature and improve coral–sea surface temperature calibrations and how these measurements relate to large-scale climate phenomena
improve quantitative sea surface temperature (https://www.clim-past.net/13/629/2017/) estimates from corals (including uncertainties) as a prerequisite for proxy data assimilation (http://pastglobalchanges.org/download/docs/magazine/2017-3/PAGESmagazine_2017(3)_162.pdf) with climate models
reduce uncertainties of fossil coral reconstructions by replication studies and numerical modeling.
convene a joint session (http://meetingorganizer.copernicus.org/EGU2018/session/28768) at the European Geosciences Union 2018 General Assembly to foster international collaboration
convene a PAGES CoralHydro2k (http://pastglobalchanges.org/ini/wg/2k-network/projects/coral-hydro/meetings/127-pages/1744-coralhydro2k-icp-19) side meeting on 1 September 2019 in conjunction with the 13th International Conference on Paleoceanography (ICP13 (http://www.pastglobalchanges.org/calendar/upcoming/127-pages/1722-13th-conf-paleocean-19)) in Sydney, Australia
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Citation: Zinke, J., M. Pfeiffer, and T. Felis (2018), Reconstructing climate and environment from coral archives, Eos, 99, https://doi.org/10.1029/2018EO096071. Published on 09 April 2018.
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