

Combining shell-based isotope records with numerical model simulations to investigate the time of emergence of widespread warming of the western North Atlantic shelf

Whitney, N.M.; Wanamaker, A.D.; Ummenhofer, C.C.; Johnson, B.; Cresswell-Clay, N.; and Kreutz, K.J.

Abstract

The Gulf of Maine and surrounding western North Atlantic shelf are some of the fastest warming regions of the world's oceans. The lack of long-term observational records from this area inhibits the ability to assess the timing and initial causes of this warming and consequently accurately predict future changes to this ecologically and economically important region. Here we present oxygen, nitrogen, and radiocarbon isotope data measured in *Arctica islandica* shells collected in the western North Atlantic to better understand the past temperature and ocean circulation variability of the region over the last 300 years. We combine these results with output from the Community Earth System Model Last Millennium Ensemble simulations to assess the temporal and spatial context of these isotope records. We find that the isotope records capture the end and reversal of a millennium-scale cooling trend in the Gulf of Maine. Last Millennium Ensemble single-forcing simulations indicate that this cooling trend appears to be largely driven by volcanic forcing. The nitrogen and radiocarbon records indicate that ocean circulation is in part driving the reconstructed hydrographic changes, pointing to a potential role of the Atlantic Meridional Overturning Circulation in regulating Gulf of Maine temperatures as suggested by the Last Millennium Ensemble simulations. Both isotope and model results suggest that the Gulf of Maine began to warm in the late 19th century, ultimately driven by increased greenhouse gas forcing.

Plain-language Summary

The Gulf of Maine, located off of the Eastern Coast of the United States, has experienced significant temperature increases recently. Because the instrumental record only began in 1905, we do not have a good idea of when this warming began and what may have initially caused the warming. Here, we analyze the chemistry of clam shells, which have grown in the Gulf of Maine for hundreds of years, to infer past changes in ocean temperatures and water properties. We combine these results with output from a climate model to reveal that the temperatures reconstructed from the clam shells agree well with the model during the period of overlap. Both the chemical records and the model suggest the Gulf of Maine started warming in the late 1800s as a result of increased atmospheric greenhouse gas concentrations. Before this warming began, the Gulf of Maine region appears to have been cooling. The model suggests that this cooling trend is likely due to the influence of volcanic eruptions. The chemical records from the clam shells also suggest that part of this cooling is likely related to changing ocean circulation patterns.