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Sunspots, Sea Changes, and Climate Shifts

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Does solar activity or ocean circulation—or both—drive changes in the atmosphere?

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Natural materials such as shells, ice, corals, and tree rings contain clues to help scientists piece together how our oceans, atmosphere, and land have changed in the past. The history of the Earth is recorded in many different chemical codes and languages, however, so we geochemists and paleoceanographers create tools that help us translate what the planet is telling us.

My research focuses on developing tools to trace environmental changes that occurred over millennia and centuries, and even over decades and years—long before humans were recording them. The trouble is that sometimes these paleo-science tools give us conflicting information; we construct or interpret a story of the past, and then new observations upset that story.

Recently, my colleagues and I encountered such a problem. While some environmental clues tell us that the sun had a crucial role in ancient atmospheric changes on Earth, we found other clues suggesting that the oceans also play a central part. My research group is looking closely at the environmental tracers themselves to see if our current history of the Holocene Epoch (the past 10,000 years or so) is a work of fiction or nonfiction.

Follow the isotopes

One of our most important tools is an isotope of carbon known as radiocarbon, or ^{14}C. It is incorporated into living and nonliving things and then radioactively decays at known rates into daughter isotopes. It is incredibly useful for dating events in Earth's past. However, radiocarbon fascinates me for a different reason: It is quite valuable as a geochemical tracer of how carbon cycles through the Earth system.

The amount of radiocarbon in the atmosphere and in the surface of the ocean is controlled by changes in two things: how much radiocarbon is produced in Earth's atmosphere and how it is distributed among various places on Earth—in the atmosphere, in living things, and particularly, in the deep ocean.

Radiocarbon is generated by cosmic rays that penetrate Earth's upper atmosphere. When the sun is more magnetically active, more sunspots spew more radiation; that blocks cosmic rays from reaching our celestial neighborhood, and less radiocarbon is produced. When the sun is less active, fewer cosmic rays are blocked, and more radiocarbon is created.

Cosmic rays also produce beryllium-10 (^{10}Be) in the atmosphere, making it another useful isotope to trace the sun's activity. More solar activity generates less ^{10}Be, and less gets incorporated into snow that falls out of the atmosphere and accumulates on glaciers. Analyzing cores from glaciers, scientists can reconstruct past levels of ^{10}Be and solar activity.

There is a significant difference between beryllium and radiocarbon, however. Unlike beryllium, radiocarbon from the atmosphere dissolves into the ocean surface. The oceans' circulation sometimes draws down radiocarbon from the surface and mixes it into deeper waters, where it decays over time. So the amount of radiocarbon in the atmosphere can also be influenced by the oceans.

What goes around comes around

My colleagues and I ran into our problem in the process of developing a record of climate changes as the Earth was emerging from the last ice age, about 15,000 to 11,000 years ago. We examined sediments cored from the seafloor in the Cariaco Basin off Venezuela. The sediments accumulate in layers over time, and they contain fossil shells of surface-dwelling microscopic marine animals. The shells incorporate radiocarbon and other isotopes from seawater that existed when the animals lived, and hence provide a record of past ocean conditions.

We were trying to correlate the timing of abrupt shifts seen in the Cariaco marine records with climate shifts on land that were detected by other researchers using ^{10}Be in ice cores and ^{14}C in tree rings. We got a near-perfect match of events.

The problem is that the fit was too good. The marine and terrestrial records of radiocarbon should *not* be a one-to-one match. Because the oceans draw down a portion of dissolved radiocarbon into the depths, there should be less radiocarbon in surface waters (and in fossil shells) than in the atmosphere.

A possible explanation for this discrepancy is that the oceans' deep circulation sometimes stalls—a periodic phenomenon that we now know can drive major global climate changes. When these slowdowns in ocean circulation occur, less radiocarbon in the ocean surface is drawn down to the depths, leaving more radiocarbon to accumulate in the air and sea surface.

So if radiocarbon levels in the atmosphere increased solely because of changes in solar activity, then beryllium and radiocarbon deposits on land would have increased; seafloor deposits would have increased, too, but not as much. On the other hand, if the radiocarbon changes were caused by a shift in ocean circulation, marine sediments and terrestrial tree rings should agree—as they seem to—but then beryllium levels should not have increased.

Muddy, but telltale, clues

As paleoclimatologists, our instinct is to say that changes happened for one reason or another—either the sun caused the change, or the ocean did. But perhaps it is both. Perhaps the sun, in triggering changes in isotopes, also triggered small changes in temperatures or another process that slowed deep ocean circulation—which, in turn, would accelerate and amplify the isotopic changes.

Such a scenario is speculative and highly controversial. We cannot build such a case from just one event in geologic time, so now we are trying to learn more from the rich data trove of Cariaco Basin sediments. The ocean basin is a unique place, where a confluence of environmental conditions makes its sediments very sensitive detectors of climate changes.

So now we are going back to our seafloor cores, hoping to analyze the records they preserve of global climate at other times in the past 10,000 years, when substantial and somewhat abrupt changes occurred. Will those periods show the same mysterious and contradictory mix of solar activity and ocean cycling? Only the mud will tell.

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