Letter From the Desk Of David Challinor
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The climate of the relatively small fraction (3/10) of the globe in which humans live is primarily controlled by the circulating patterns of ocean currents. Most people are familiar with two of these currents: the Gulf Stream, an easily visible band of warm, blue water that flows northeast across the Atlantic, and the Humbolt Current, a cold, nutrient-rich stream that flows north along the west coast of South America. When the Humbolt reaches Ecuador (on the equator), it turns due west and runs through the Galapagos Islands, creating favorable conditions for such cold water creatures as penguins and fur seals. These ocean currents are but two examples of many others that also influence weather on adjacent land masses.

People tend to live near the coast because the oceans moderate the temperature extremes. Although there are hundreds of well-known currents flowing through the world's oceans, scientists are still not entirely clear how they are driven, but some patterns are beginning to emerge. This letter will discuss what appears to be the greatest of all the oceans' circulating currents and the energy source that drives it.

A description of this great current appeared in a fascinating article by Wallace Broecker, a distinguished oceanographer, in Natural History (10/87, pp. 74-82), entitled "The Biggest Chill: when ocean currents shifted, Europe suddenly got cold. Could it happen again?" Broecker raises the specter of another ice age and how it might occur. He studied the cyclical changes in the polar ice caps over the past million years and, matching his data with that of a Swiss colleague, Hans Oeschger, Broecker noted that the Earth's ice ages have come and gone with surprising frequency over the past 100,000 years. Analysis of air bubbles trapped in ice cores taken continuously from Greenland's ice cap since the 1960's shows that marked increases in global temperatures have always correlated with large changes (20% increase) in global CO_2. Oeschger postulated that there could be a mechanism that affected ocean circulation systems that in turn resulted in ice ages. Broecker advanced the concept of a global system he called "the great ocean conveyor belt" (see attached map). To understand how it works, the following basic facts are crucial:

1) Cold water is heavier than warm water and will sink below it.
2) The saltier the water, the heavier it becomes, thus sinking below less salty water.

With these facts in mind, I will describe the great current that flows in the Atlantic. Envision a huge, discrete volume of water (20 times the content of all the earth's rivers) flowing north after clearing the Cape of Good Hope (at the tip of South Africa). As it passes the equator, the ocean's surface temperature is warmed. The water continually evaporates, making the ocean increasingly saltier. North of 35° latitude (just above a line between Bermuda and the Azores), a giant pumping action that is always present at a lower rate increases greatly in winter when cold air from the Canadian arctic blows eastward over the warm ocean surface. The amount of heat transferred from the waters of the north Atlantic to the air is staggering, representing about 30% of the total solar energy absorbed by the Atlantic's surface as it moves north. This enormous heat transfer, coupled with the prevailing westerly winds, allows London and Paris to enjoy roughly the same climate as New York City, despite being more than 600 miles further north.

Meanwhile, on the ocean surface, west of Ireland and south of Iceland, the temperature of the winter chilled water has dropped from about 50°F to only 37°F. The water, now both colder and saltier than ocean surface water any place else in the world, sinks to the bottom and flows south. The pump analogy posits the surface heat loss and evaporation as the upstroke and the sinking of dense, cold, salty water as the downstroke.

This explanation has been extremely simplified to make the system understandable to a lay person. It took incredible insight and vision to imagine such a concept, but continuing data collected from ice cores near the poles and from deep sea sediments support Broecker's hypothesis. In other words, the patterns of abrupt shifts between ice age conditions and warm periods -- even in time scales as short as a decade -- continue to be confirmed.

Interestingly the conveyor belt also operates in the Pacific, but in the opposite direction. Deep cold water moves north, and as it warms and reaches the surface it loops south to pass between Australia and Southeast Asia into the Indian Ocean. Broecker emphasizes that the mechanism driving this giant conveyor belt can switch on and off. When not operating, Europe freezes with a climate similar to Labrador's. Fortunately, the conveyor belt has been running relatively stably for the past 14,000 years, with one short 700-year-long ice age about 12,000 years ago called the Younger Dryas. Before describing what caused this glitch, I should explain briefly what is thought to cause glacial periods in the first place.

In the early 1940's a Serbian scientist, Milankovitch, hypothesized that the Earth's orbital plane around the sun tilted slightly every 100,000 years. When the orbit was tilted, the seasonality of the high latitudes was reduced; that is, the difference between summer and winter temperatures narrowed to the point where not enough ice melted in the summer to offset the accumulation in the winter. Under such conditions, ice built up and the north Atlantic stayed very cold; not enough surface water evaporated to increase salinity, thereby switching off the pump. When the Earth resumed its normal orbit, summer temperatures in the high latitudes increased enough to have a net ice-melt. In North America melt-water from the glacier covering the continent flowed into the Gulf of Mexico through the Missouri, Mississippi and Ohio river basins and by 14,000 years ago global temperature had risen enough to restart the pump.

Then as the retreating North American glacier moved north during the next 2,000 years, the melt-water shifted from draining primarily into the Gulf of Mexico to emptying into the Gulf of St. Lawrence. The volume of this water must have been enormous, so great that it reduced the salinity of the north Atlantic's surface water and kept it from becoming dense enough to sink and thus power the pump. So began the 700-year-long Younger Dryas period. The name comes from dryas, a major plant species of the tundra that re-vegetated soil exposed by the retreating glacier. In the 2,000 years after the glacial front melted north, the tundra had been replaced by forests. Unexpectedly, pollen samples from bog cores indicated that the forests were replaced by tundra plants for the 700 years during which the volume of fresh glacial melt-water flowed into the north Atlantic through the St. Lawrence; this was sufficient to stop the pump again.

What this letter attempts to show is that the Earth's climate is not orderly and can be upset relatively easily. Any influx of fresh water into the north Atlantic great enough to reduce average salinity by only one or two grams per liter could shut down the conveyor belt. The past 12,000 years during which the system has been running corresponds directly to the flowering of humankind. Agriculture, cities, technology, arts and the evolution of sophisticated human culture have all taken place in this relatively short time. Paleoclimate records, where they are accurate enough to compare with today's conditions, show no equivalent period that has been significantly warmer than it is today. How far can ubiquitous humans push the system? Greenhouse warming of the globe should be a valid concern for everyone. Will excessive warmth shut down the great conveyor belt just as glacial periods have? Scientists do not know the answer, but surely for the sake of future generations we must be prudent and curb our excessive use of environmentally expensive energy.

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