SCIENTIFIC AMERICAN FRONTIERS PROGRAM #1505 "Hot Planet - Cold Comfort"

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The Sea's Greatest River
Water, Water Everywhere
Only a Little Ice Age

ALAN ALDA Hello and welcome to Scientific American Frontiers. I'm Alan Alda. This week we're going to talk about the weather. You may have seen last summer's blockbuster movie about a catastrophic change in the global climate -- New York gets flash-frozen, it snows in Delhi and enormous hailstones batter Tokyo. It all made for great entertainment, but was the science any good? When the movie came out, scientists were unanimous in saying it couldn't happen -- or at least that it couldn't happen like that. A few, though, acknowledged that there was a grain of truth behind the hype, and behind the hype is where we're going with this program. We're going to meet scientists who are figuring out how the enormous streams in the world's oceans circulate, and how changes in them might cool us down. We're going to link those changes to a warming climate. And we're going to see what the reality of a changing climate can look like, in Alaska. That's coming up on tonight's episode, Hot Planet-Cold Comfort.

THE SEA'S GREATEST RIVER

ALAN ALDA (NARRATION) We're at the Woods Hole Oceanographic Institution on Cape Cod, Massachusetts, and we're with Ruth Curry. She studies the oceans, but she doesn't have to leave her chair to do it.

RUTH CURRY Here in this office I have the world's oceans at my fingertips, basically. I have been collating millions and millions of oceanographic profiles from people who have been out observing the ocean for the last hundred years, or so. I have them all here stored in my computer, and I've got analysis software that I use, and I explore the oceans.

ALAN ALDA (NARRATION) For the last 10 years, Ruth Curry has been looking closely at the saltiness of the oceans. As we'll see, ocean saltiness helps drive enormous currents which move water around the globe — especially the one that Jules Verne called "the sea's greatest river," the Gulf Stream. The Gulf Stream is like a giant heat pump, bringing warm water up north.

RUTH CURRY The warm surface waters come up from the tropics, through the Caribbean, and Gulf of Mexico and around Florida.

ALAN ALDA (NARRATION) Satellite images, based on sea temperature, show that the Gulf Stream is not a river. It's a broad mass of swirling water flows.

RUTH CURRY When they reach the coast of North Carolina they start to move offshore. And the Gulf Stream flows northward and eastward. A portion of that then branches southward, like this. But another portion of it branches northward, and it brings those warm waters eastward across to Europe, up by Great Britain. It flows into the Nordic Seas on the coast of Norway.

ALAN ALDA (NARRATION) Here in the Norwegian and Greenland Seas, a key process takes place. The warm surface waters are cooled by Arctic winds. That makes them sink into the deep ocean basin here, but in the process, cold water is pushed over an ocean ridge that runs between Scotland and Greenland. It's an enormous pump, which drives the Gulf Stream. The cooled water overflows down the ridge, back into the Atlantic.

RUTH CURRY They flow along the coast of Greenland. They follow the western boundary, southward.

ALAN ALDA (NARRATION) The cold southward flows are now deep — they're underneath the warm Gulf Stream that's flowing north on the surface.

RUTH CURRY They cross underneath the Gulf Stream and then they continue their flow pattern towards the equator.

ALAN ALDA (NARRATION) In the 1980s a Columbia University scientist called this a "great conveyor belt." It brings a third of all the sun's energy that falls on the Atlantic, up to the northeast US, Europe and Scandinavia. It's the largest heat pump in a global ocean conveyor that redistributes heat around the planet. Oceanographers have been sampling the world's seas for a long time. One of the basic things they look at is salinity — how much salt is in the water. Salinity varies -- it's high in the tropics, where the sun evaporates moisture into the atmosphere, and low towards the poles, where precipitation adds fresh water. Saltwater is heavy, while freshwater is light. We'll see how vitally important that is, in a moment. At Wood's Hole, Ruth Curry has been tracking the salinity in the Greenland and Norwegian Seas — the region where the ocean conveyor cools, sinks and heads back south. These decorative panels are not the latest wallpaper designs. In fact they show, in an exaggerated view, the shape of the sea floor from the Arctic and the Greenland Sea on the left, down through the Denmark Strait between Greenland and Iceland, and on into the Atlantic. The upper view shows how heavy, or dense, the water is, the lower view how salty. In the 1950s the Greenland Sea was dense and salty. This is the ocean conveyor at work — the water sinking as it cools, then spilling out through the Denmark Strait into the Atlantic. Twenty years later things were changing. Freshwater — the purple color — was washing in from the north, on the left. RUTH CURRY We're now starting to see in the seventies the incursion of this fresh water. It's beginning to come down from the Arctic. As we continue on into the seventies and eighties, we see that freshwater washed all the down to the bottom of the ocean. In the nineties we see this very, very fresh water -- it's beginning to accumulate at the surface. It's filled in the sub-polar basins and the density, that mountain of density has basically collapsed. The red colors are now only found in the deepest part of the Greenland Sea. Here's the situation in the last five years or so, and we see that this dark blue, or purplish waters, indicates that a tremendous layer of freshening has spread across the Nordic Seas and into the sub-polar basins.

ALAN ALDA (NARRATION) The heart of the ocean conveyor — its pump — is saltwater cooling, and sinking. But freshwater is lighter than saltwater — it floats on top. So if the Nordic Seas get fresh enough, the pump could be threatened.

RUTH CURRY No matter how cold the waters get, they cannot sink down into the deep ocean. Dense waters will not be formed, and that will slow, and perhaps even stop the ocean conveyor belt.

ALAN ALDA (NARRATION) Remember what the conveyor belt does — it brings an enormous amount of heat from south to north. So if it does ever stop, a lot of people will feel the consequences.

RUTH CURRY Places like northern Europe, Greenland, Iceland and the eastern United States would especially see changes, on the order of two to five degrees centigrade changes. And what that translates to is difficult to describe exactly, but if you can remember some of the coldest winters you might have experienced on the east coast of the United States, that's what we could be seeing again.

ALAN ALDA (NARRATION) In our next story we're going to ask where all that freshwater in the Nordic Seas is coming from.

WATER, WATER EVERYWHERE

ALAN ALDA (NARRATION) We've come across town to another Woods Hole research organization. It's the Marine Biological Laboratory. There's a group here that specializes in freshwater research.

BRUCE PETERSON They're coming up with calculations...

ALAN ALDA (NARRATION) For the last 10 years, Bruce Peterson has been leading a team studying how freshwater works at the top of the globe, in the Arctic Ocean.

BRUCE PETERSON Much of the freshwater that enters the Arctic Ocean doesn't necessarily come as precipitation directly on the Ocean, it comes as runoff from this watershed. For orientation, you have Greenland here, Pacific Ocean here, the Atlantic Ocean here, and for reference here is Alaska, this would be Canada, and now you have Eurasia over on this side. Now two thirds of the watershed that actually contributes freshwater to the Arctic Ocean is on this Eurasian side.

RUSSIAN CHILDREN Hello. Hi. Hello.

ALAN ALDA (NARRATION) We're in Zhigansk, in Siberia. There's excitement in town because school's out. Spring's around the corner, and the ice on the river is breaking up. Way out there, the river is flowing fast — north towards the Arctic Ocean. This is the Lena River — it's as big as the Mississippi. Russia's Arctic rivers are closely monitored, with their heights and flow rates recorded throughout the year — a practice that began in Soviet days. The records for the six largest Russian Arctic rivers go back 70 years — twice as long as any of the other rivers that flow into the Arctic Ocean. That's long enough for Bruce Peterson's team to reliably pick up trends in the amount of freshwater being discharged.

BRUCE PETERSON The amazing thing to us, when we looked at these records, is that -- two, three, four, five of those six watersheds were ramping up in discharge, especially in the last 30 to 40 years.

ALAN ALDA (NARRATION) River flow is simply a reflection of the amount of rain and snow falling on the land that the river drains. The global pattern in which moisture evaporates in the tropics, and precipitates near the poles, has been ramping up in recent decades -- just like the Russian rivers. Tropical waters are getting measurably saltier, and polar waters are getting noticeably fresher, as Ruth Curry found. For climate scientists and oceanographers, there's a simple explanation for this.

RUTH CURRY The warming of our planet and especially the warming of our surface oceans is removing freshwater through increased evaporation from the low latitudes. That freshwater is being precipitated at high latitudes.

ALAN ALDA (NARRATION) This is what happens on a warmer earth — there's just more heat driving weather systems. There's no doubt increased river flows are freshening the Arctic Ocean. But that might not be the only cause of its freshening. We're in the St. Elias Mountains, in southern Alaska. The region has been called North America's Himalayas — a 600-mile stretch of mountain ranges. In front of us is part of Jeffries Glacier, an immense river of snow and ice.

PAUL CLAUS Ready to roll? Looks like a beautiful day.

ANTHONY ARENDT Yeah. Looks great.

ALAN ALDA (NARRATION) Today, Anthony Arendt and Paul Claus are going glacier flying. PAUL CLAUS Are you good to go?

ANTHONY ARENDT Yup.

PAUL CLAUS Power's on. Everybody's clear?

ANTHONY ARENDT OK, the gyro is zeroed and we're ready for takeoff.

ALAN ALDA (NARRATION) They're flying out of the strip at Paul's remote hunting lodge. He's an expert bush pilot, who works with the glacier research group from the University of Alaska, Fairbanks. They head over to Jeffries Glacier, about 40 miles away and 6,000 feet up. These mountains have some of the largest glaciers in the world. For the last 10 years the Fairbanks group has been keeping track of a hundred representative glaciers in Alaska and Canada. They do it with precision flying. Year after year, they've flown the same tracks down the glaciers, bouncing a laser altimeter off the surface as they go. They end up with the exact heights of the glaciers, accurate to within about 12 inches.

ANTHONY ARENDT I'll start logging right when you cross the pass.

ALAN ALDA (NARRATION) Paul banks the plane round to the center line of the glacier, while Anthony prepares to log their position in relation to GPS satellites, along with their exact height above the glacier.

ANTHONY ARENDT OK, laser's in range right now, 200 meters. Looking good. And we're logging. 50 meters. 25 meters. It looks good. We'll just fly right down the center line.

PAUL CLAUS Alright.

ANTHONY ARENDT 50 meters.

ALAN ALDA (NARRATION) They also plot the terminus point in the valley where the glacier transforms into a river.

ANTHONY ARENDT Pretty distinct terminus on this one.

PAUL CLAUS Oh, I guess. Ice ends right now.

ANTHONY ARENDT OK.

ALAN ALDA (NARRATION) Back at the lab there's a lot of number crunching to come up with the latest dimensions of each of their hundred glaciers.

KEITH ECHELMEYER This is our glaciology lab É

ALAN ALDA (NARRATION) Keith Echelmeyer started the glacier project, and used to do all the precision flying himself. They found that, compared to the maps of 50 years ago, the glaciers have shrunk dramatically. And that's not all.

ALAN ALDA Is it really accelerating? What do you mean, accelerating?

BY VALENTINE We find that, on average, every year, that the glaciers are thinning by a half a meter. Every year.

ALAN ALDA Every year.

BY VALENTINE So. You know. So...

ALAN ALDA You mean, from the '50s up through the '90s every year they lost an average of a half a meter.

BY VALENTINE Half a meter.

ALAN ALDA Wow.

BY VALENTINE Then, if you look at the period from the early 1990s to 2000, 2002, that rate goes up to 1.8 meters per year. So nearly two meters every year of ice is lost on average, over the entire surface of the glacier.

ALAN ALDA So that really is zipping ahead, isn't it?

KEITH ECHELMEYER Oh, it's zipping ahead, really a lot. And if that continues in the future, that's what I was saying, a lot of these glaciers won't be here.

ALAN ALDA (NARRATION) The findings translate into staggering volumes of water added to the oceans — 900 trillion gallons just from Alaska and western Canada in the last 50 years, enough to raise sea levels by about a quarter of an inch, worldwide. Only a fraction of that fresh water finds its way into the Arctic Ocean, but the point is this -- these are the most closely studied glaciers in the world, and there is no doubt they are melting. The planet's largest accumulation of ice outside Antarctica is in Greenland. If it's behaving in the same way, that could dump a lot of freshwater precisely at the ocean conveyor belt's most vulnerable point. The outlook for the conveyor — the thermohaline circulation, as scientists call it — could change rapidly.

RUTH CURRY At the present rate of freshening, the system could go on for decades, or maybe even hundreds of years and not alter the thermohaline circulation. On the other hand, if we had a sudden release event -- something like a big chunk of the Greenland ice sheet breaking off and entering the ocean and melting, or else a pool of glacial meltwater forming a lake and then an ice dam breaking and having a sudden release of that water into the Nordic Seas -- then that's the sort of thing that might precipitate an actual change in the ocean circulation.

ALAN ALDA (NARRATION) In our final story, we'll see that sudden changes like this have happened before. We'll trace how scientists reconstruct past climate events. And we'll ask what a stalled ocean conveyor could do to the weather.

ONLY A LITTLE ICE AGE

ALAN ALDA (NARRATION) We're in medieval Europe, and it's bitterly cold. For several centuries, ending around 1850, Europe was gripped by what's called the Little Ice Age. In its coldest years it was catastrophic. In 1693 the harvest failed and millions died. In 1709 a French priest wrote, "Most of the hens have died of cold, and the beasts in their stables." In fact this was a global phenomenon — New York harbor froze over in 1780, and there were mass migrations of Native Americans seeking warmer areas. It's not clear what caused the Little Ice Age — perhaps volcanic dust shading out sunlight, combined with changes in the sun itself. But what it shows is how disruptive even small changes in temperature can be. The average cooling in the Little Ice Age was around three degrees. But averages are misleading — they hide much larger swings from day to day, or year to year. Reconstructing the climate of the past is a major scientific preoccupation, now that there is so much attention on what we might be doing to our climate today. One of the best places to look for traces of past climate is at the bottom of the ocean — in the thick layers of sediment that accumulate over the centuries, and millennia. This crew is collecting long sediment core samples off the coast of Brazil. They're brought up in plastic pipes that have been rammed into the sea floor. Teasing out what the sediment cores have to say about past climate is a long and painstaking process. First the core is split. One half is for analysis, the other is held for reference. Oceanographers have collected thousands of sediment cores from all the world's oceans. They're stored in enormous, warehouse-sized libraries — like this one at the Woods Hole Oceanographic Institution. Unlocking the knowledge in the library starts like this. Most of the sediment is just silt, washed out from the continents in rivers. What they're looking for is these tiny white grains. The grains are actually shells — skeletons of plankton that lived in the ocean, died and sank to the bottom. There's a wealth of information in the shells. Some plankton like cold water, some warm — so that's a kind of thermometer. The shells are made of calcium carbonate, and its component atoms can be analyzed. The carbon can be radiocarbon dated, so you know when the plankton were living. This setup is used to extract and purify carbon from the shells. It's part of a US national radiocarbon dating lab at Woods Hole. Then the carbon samples go next door to the nuclear accelerator, which counts the different carbon atoms and figures out their age. You can also analyze the oxygen from the shells, to reveal the temperature of the water they lived in. A parallel set of measurements has been made on air bubbles trapped in ice cores drilled from the Greenland ice sheet. The result has been startling — a classic scientific paradigm shift. Rather than what we'd thought, since the end of the last Ice Age, 12,000 years ago, earth's climate has not been stable. It's cooled abruptly, several times.

LLOYD KEIGWIN There's on the order of six or eight events that we see in sediment cores, and they correlate to events that we see in Greenland ice cores as well. The most recent of them would be the Little Ice Age.

ALAN ALDA (NARRATION) The Little Ice Age had been regarded as a curious anomaly, but now here was a whole bunch of mysterious events. In a lucky coincidence, the ocean sediments and Greenland ice cores were giving up their secrets just as, in the 1980s and 90s, our understanding of the ocean conveyor belt was growing. Scientists are now putting the two together. Take the cooling event that occurred eighty two hundred years ago. At the time, there were still remnants of ice sheets around Hudson Bay. An enormous lake of meltwater had accumulated behind the ice. Then suddenly it burst through the blockage, flooded into the Bay and out to the ocean.

LLOYD KEIGWIN Very abruptly, in as little as one year around eighty two hundred years ago, the water finally bored its way through the ice and the whole system collapsed. There's a very widespread cooling known all around the North Atlantic region that's exactly coincident, as nearly as we can tell, with this massive discharge of ice and water out of Hudson Bay. So there's a mechanism.

ALAN ALDA (NARRATION) The cooling mechanism is simply that the flood of freshwater shut down the ocean conveyor — the thermohaline circulation. At least one other cooling event was probably triggered this way. Could this happen today? The ice in our warming planet is definitely on the move. Over the last few years thirteen hundred square miles of Antarctic sea ice have broken off, and drifted away. The Greenland ice sheet is more than a million cubic miles of ice, sitting right next to the thermohaline circulation pump that drives the ocean conveyor. Scientists like Ruth Curry are well aware of the potential.

RUTH CURRY We know that Greenland is melting. We know that it is changing its characteristics -- the amount of slippage is increasing as a result of the accumulation of freshwater at the base of the glaciers. I think that the Greenland ice sheet is probably the biggest wild card in this equation. If a large chunk of that should fall off into the ocean, then that could be enough to produce the amount of freshwater that would then have an impact on the thermohaline circulation.

ALAN ALDA (NARRATION) We're back on the Lena River in Siberia. The next step for Bruce Peterson's group is to analyze the waters of the big Russian Arctic rivers, and define chemical fingerprints for them. Then they can track the water once it's out in the ocean, and begin to tie down how different sources — rivers or melting glaciers — are contributing to the overall freshening.

MAX HOLMES There it is.

ALAN ALDA (NARRATION) At the same time, Ruth Curry's colleagues are installing a system of deep moored instruments to directly monitor the ocean conveyor, as it flows north, and south, off the east coast of the US. If the ocean conveyor shuts down, it could happen gradually -- as a result of the freshening of the Arctic Ocean; or abruptly -- if there's a big ice event in Greenland. Either way, scientists will be watching.