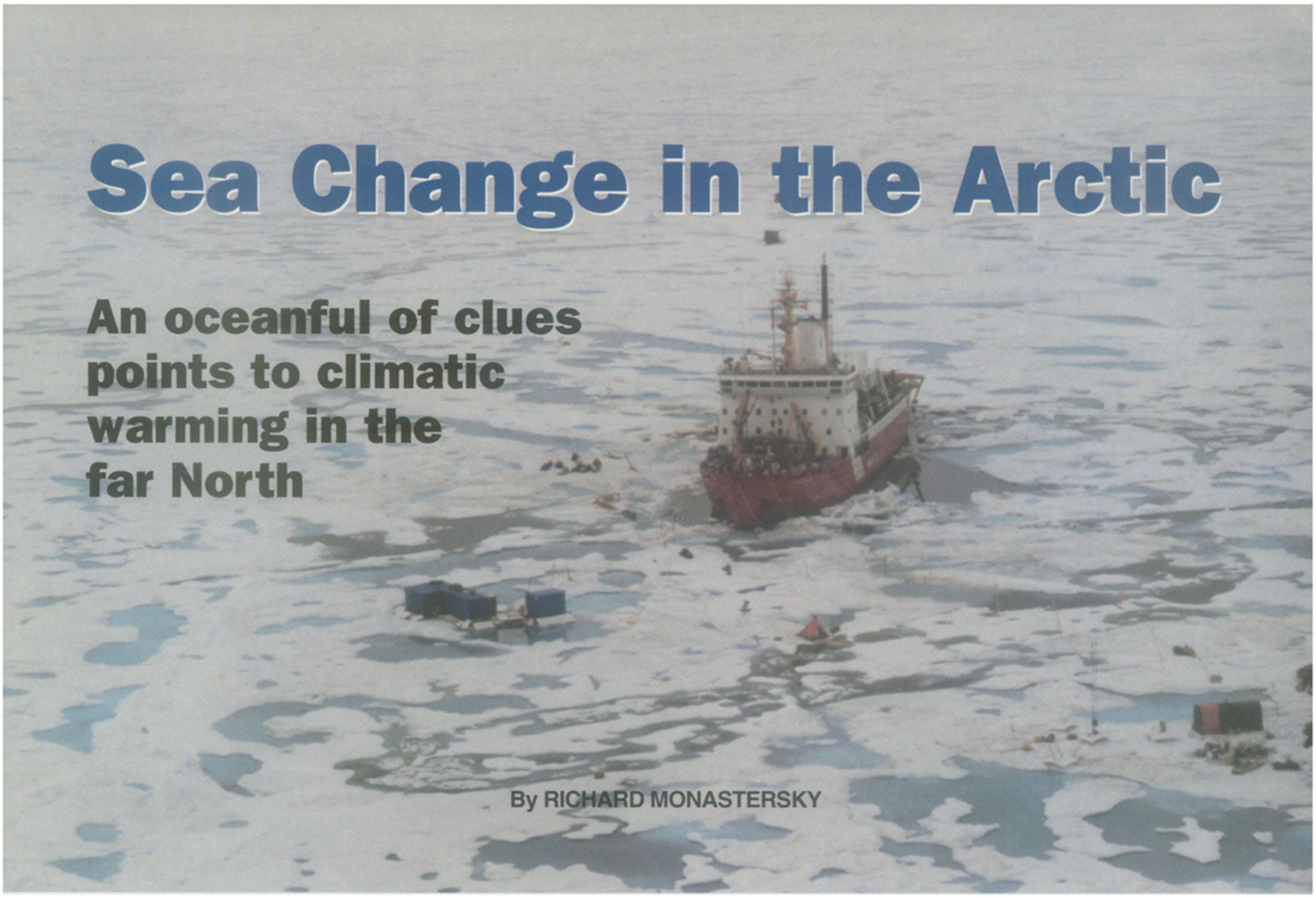
Sea Change in the Arctic

An oceanful of clues points to climatic warming in the far North

By RICHARD MONASTERSKY



At home on the Arctic Ocean: During their year frozen into the ice, scientists on the Canadian ship Des Groseilliers *saw temperatures range from a low of -42°C in late December to a high of almost 1°C in July, when substantial melting occurred around the ship.*

The first sign that something was wrong came just a few days after the icebreaker *Des Groseilliers* left Tuktoyaktuk, a port on the Arctic coast of western Canada. Steaming north with a full load of 20 scientists and provisions for 18 months, the Canadian coast guard ship was heading for a date with the Arctic pack ice—the perennially frozen layer that covers the top of the globe like a white skullcap.

Old hands at polar research, such as oceanographer Miles G. McPhee, expected to meet the ice between 71° and 72°N. That's where the southern edge of the pack showed up in the 1970s, when McPhee made several trips far into the Arctic. Two decades later, the Canadian icebreaker cruised past 72°N at full speed, with no ice in the water to slow its progress. McPhee, who runs a research company out of Naches, Wash., wondered silently, "Oh my God, where did all the ice go?"

The case of the shrinking pack ice is only one of many climatic conundrums troubling scientists who study the Arctic. In recent years, researchers have discovered myriad signs of changes in the far North, affecting everything from the ocean currents flowing 1,000 meters beneath the ice pack to the howling winds at the top of Earth's atmosphere. "I think the changes are verging on what could be called dramatic," says John M. Wallace, an atmospheric scientist at the University of Washington in Seattle.

Some aspects of the shifting Arctic weather resemble the patterns expected from greenhouse warming, leading scientists to wonder whether they are witnessing early warning signs of conditions to come during the next century. The polar regions, especially the Arctic, are regarded as the climatic equivalent of canaries in a coal mine. The poles are the places on Earth most sensitive to global warming. With the canaries looking distinctly wan, the search is now on to determine what has caused their decline.

These are some of the scientific issues that propelled McPhee and his colleagues northward on the *Des Groseilliers* in the fall of 1997. Following the plans of the $19.5 million international research project, the Canadian icebreaker finally plowed into the pack ice, cut its way to the middle of a large floe, and then stopped its engines at 75°N.

For an entire year, the ship remained frozen amid the ice, dragged 2,800 kilometers on a roundabout course northwest across the Arctic Ocean, a landless expanse of water and ice. Over that time, planes ferried a total of 170 researchers out to the ship in shifts of several weeks to months. The scientific teams fanned out across the nearby ice to collect measurements on how heat shuttles among the ocean, the sea ice, and the atmosphere through the different seasons. They called the project SHEBA, an acronym for Surface Heat Budget of the Arctic.

From the beginning, SHEBA taught investigators to question the prevailing ideas about the Arctic. Project planners had expected to park the icebreaker amid floes measuring 3 m thick, the kind of ice seen in the 1970s during the last major U.S. Arctic initiative. The SHEBA crew, however, was dismayed by what it encountered in 1997.

"When we went up there, the first problem we had was trying to find a floe that was thick enough. The thickest ice we could find was 1.5 to 2 m," says SHEBA chief scientist Donald K. Perovich of the U.S. Army Cold Regions Research and Engineering Laboratory in Hanover, N.H.

Once the crew set up the ice station, another startling fact came to light. During the first few weeks of work, McPhee and his colleagues found that the shallow waters of the Arctic Ocean were warmer and less salty than they had been 22 years earlier. This observation implies that a significant quantity of ice had melted during the previous summer, says McPhee's team, which published the SHEBA finding in the May 15, 1998 Geophysical Research Letters.

More shocks came toward the end of the project in October 1998. "The big surprise of our work was that the ice ended up at the end of the year thinner than when we had started," says Perovich. The warm winter and long summer of 1988 had shaved off about one-third of a meter from the already thin ice.

SHEBA investigators suggest that some of the changes they saw could have stemmed from the 1997–1998 El Niño in the equatorial Pacific, although this temporary warming can't explain all the findings. Arctic sea ice has been declining for many years.

In 1997, researchers from NASA's Goddard Space Flight Center in Greenbelt, Md., reported that the area covered by sea ice decreased by more than 5 percent between 1978 and 1996. Other satellite measurements of the sea ice have revealed evidence of increased summertime melting since 1979 (SN: 2/21/98, p. 116).

Sea ice is only a thin skin over the Arctic Ocean, but in many ways it serves as the linchpin of the region's climate and perhaps that of the whole globe. If the pack diminished substantially, climate models predict big changes in the ocean and atmosphere. The reason stems mainly from something scientists call the ice-albedo feedback.

Because ice is so bright, it reflects more than half the sunlight that hits it during summer. The dark water, by contrast, absorbs 90 percent of the incident sunlight, says Perovich. The existence of the sea ice, therefore, keeps the Arctic Ocean cool by shielding it from solar energy.

If the ice starts to disappear, according to theory, the ocean will rapidly warm and melt more ice—a potentially runaway process that could strip the Arctic of its protective cap and allow solar energy to stream into the ocean unhindered. This ice-albedo feedback would greatly amplify the effects of greenhouse gas pollution, causing the Arctic to warm much more than the rest of the globe, according to climate models. The Arctic shift would have a domino effect, rerouting ocean currents and weather patterns further south.

Three sets of submerged mountain ridges (red) split the Arctic Ocean into separate basins. The SHEBA project studied conditions on the Alaskan side of the Arctic.

Until recently, scientists had little access to the Arctic Ocean, which served as the sparring ring for superpower submarines. With the end of the Cold War and the withdrawal of military forces, scientists started invading the region. Researchers who once sat on opposite sides of the Iron Curtain began sharing data and collaborating on projects. Since 1993, the U.S. Navy has invited oceanographers along on several submarine cruises beneath the ice pack.

In a strange confluence of climate and current events, the thaw in political tensions a decade ago coincided with an apparent shift toward warmer conditions in the North. Some of the biggest changes have occurred within the Arctic Ocean, an oblong body of water nearly one and a half times the size of the United States. The ocean is divided into four unequal basins separated by three roughly parallel mountain ranges on the seafloor—an arrangement that looks somewhat like an empty TV dinner tray.

Much of the water in the Arctic comes from the Atlantic Ocean, coursing north as a vestigial extension of the Gulf Stream. On the opposite side of the pole, water from the Pacific Ocean enters the Arctic via the Bering Strait. As the Pacific water passes through the shallow strait, it loses much of its heat to the atmosphere and consequently grows colder than the Atlantic water. The two distinct types of water meet midway in the Arctic, creating a front much like the kind that separates warm and cold air masses in the atmosphere.

Water measurements made by Russian and Western scientists indicate that the front between these two types of water bisected the Arctic Ocean for most of the past half-century. From 1949 through the late 1980s, the front generally lined up with a submerged mountain range called the Lomonosov Ridge, which runs from northern Greenland toward eastern Siberia, passing close to the North Pole.

During a scientific submarine cruise in 1993, researchers on board the USS *Pargo* found that the front had shifted substantially. The warmer, saltier Atlantic waters had pushed further into the Arctic, causing a retreat of the Pacific waters, says James H. Morison of the University of Washington, who participated in the *Pargo* cruise.

At the same time, the Atlantic-water layer over the Lomonosov Ridge warmed by 1°C, reaching a temperature not seen in the data going back to 1949, according to a January 1998 report by Morison and his colleagues in Deep-Sea Research Part I.

Other shifts have altered the layered arrangement of water in the Arctic. To understand these divisions, imagine lowering a thermometer and a salt meter off a ship in the middle of the Arctic. The uppermost layer of the ocean would be extremely fresh with a temperature near the freezing point. Below that, the instruments would pass through a layer called the halocline, where the water remains cold but grows saltier with depth. Lower still would be a thick region of relatively warm water, so dense with salt that it remains stuck on the bottom, trapped below the fresher, colder layer above.

In a series of three submarine cruises during the 1990s, oceanographers witnessed the halocline weakening in the central part of the Arctic. Early in the decade, a particularly cold sheet of halocline water straddled the Lomonosov Ridge. By 1995, however, the sheet had disappeared from the European side of this range, according to Michael Steele of the University of Washington. He and colleague Timothy Boyd of Oregon State University in Corvallis reported their finding in the May 15, 1998 Journal of Geophysical Research.

The retreat of this layer could have profound effects, says Steele, because the halocline helps stratify the Arctic Ocean, keeping the warm, deep waters from reaching the surface. "Because there is decreased stratification, there should be enhanced heat transfer from the warm layer up to the surface, and hence thinner ice," says Steele.

Data collected by British submarines show that ice has been thinning in this region for some time. In 1990, researchers with the Scott Polar Research Institute at Cambridge University in England reported that ice thickness on the European side of the Lomonsov Ridge had decreased by 15 percent between 1976 and 1987. Preliminary analysis of measurements made in 1996 now suggest that the downward trend has continued, says Cambridge's Norman Davis.

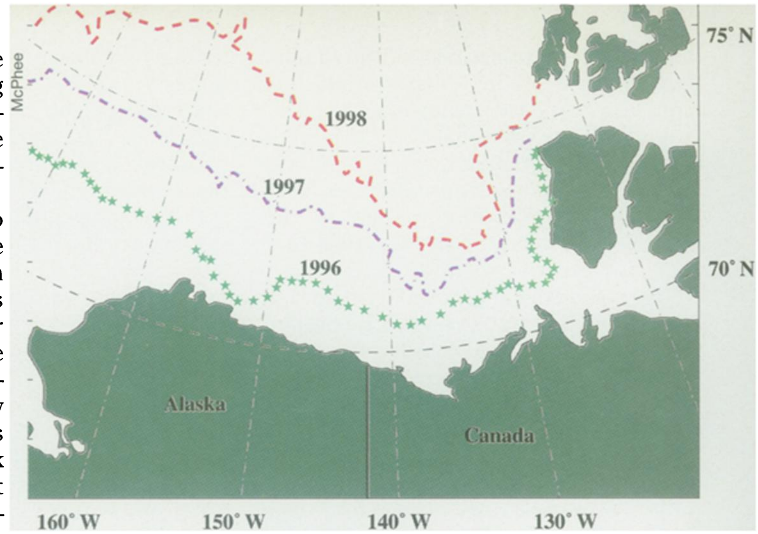
With so many signs of disruptions in the Arctic climate, scientists are looking skyward for answers. The ice pack and even the water beneath it, they suspect, are taking their cues from the pattern of winds that swirl around the edges of the Arctic. "Really, that is where it all starts," says Steele.

What's going on in the Arctic may fit into a larger picture that includes much of the globe's northern half. According to a theory proposed last year, atmospheric pressure tends to fluctuate in seesaw fashion over large parts of the Northern Hemisphere. When pressure increases over the Arctic, it decreases in a donut-shaped ring at the latitude of Washington, D.C. During the reverse part of the irregular cycle, air pressure drops in the Arctic and rebounds in the midlatitudes. Wallace and David W. J. Thompson of the University of Washington called this pattern the Arctic oscillation in the May 1, 1998 GEOPHYSICAL RESEARCH LETTERS.

Atmospheric temperatures in northern Europe and Asia dance in step with this Arctic oscillation. When the atmospheric pressure sags, air temperatures tend to rise and vice versa, says Wallace, who has tracked data going back to 1900.

For most of the century, the Arctic oscillation shifted randomly from month to month and year to year, with no distinct preference for either extreme. Recently, however, the oscillation has leaned strongly toward low Arctic air pressure and high temperatures in northern Eurasia. The shift started in the early 1970s and intensified in the late 1980s, bringing atmospheric conditions unseen in the century of measurements.

"That's the link to perhaps some of the other things going on in the Arctic," says Wallace. As the air pressure drops, the westerly winds encircling the Arctic grow stronger. The winds weaken the ice pack by pulling it apart and opening up watery channels between individual ice floes, says Wallace.



Frozen retreat: The edge of summertime sea ice in the Beaufort Sea pulled northward between 1996 and 1998, according to satellite data. Oceanographers are watching closely to see whether the ice withdrawal continues this summer.

The souped-up westerlies also alter conditions in heavily populated parts of the globe. As they scream over the North Atlantic Ocean, the winds carry more heat downwind onto land. This translates into warmer winters in northern Europe and drier winters in southern Europe. "We've seen a strong warming in high latitudes over land in large areas of Russia," says Wallace. "We're seeing changes in the circulation that are big enough in winter that people in Europe are noticing them."

The key question is, What has caused all this change? In a study using computer models of the atmosphere, a team of Russian researchers has found evidence that thinning of the Arctic ozone layer could be driving the shift in the atmosphere. As chlorofluorocarbons and other chemicals eat away ozone, the polar stratosphere cools off. In the Russian model, this cooling effect enhances the westerlies that circle the Arctic and hence reduces the atmospheric pressure there.

Greenhouse gases could also have a hand in the Arctic shift. Carbon dioxide and other heat-trapping pollutants tend to warm the lowest layer of the atmosphere—the troposphere—while cooling off the stratosphere above. Researchers at NASA's Goddard Institute for Space Studies in New York City used a computer model to investigate this split effect of greenhouse gases. They found that the combination speeds up the westerly polar winds, pushing the Arctic oscillation in the direction seen during the past 30 years, says NASA's Drew T. Shindell.

Wallace thinks there is a good chance that one or both of these human influences could have precipitated the Arctic changes. Yet he cautions against drawing any conclusions. "We have to allow some possibility that this is of natural origin," as part of a long-term cycle that will eventually reverse, he says. To rule out a natural cause, the Arctic oscillation would have to keep on its present course for another 5 to 10 years, he says.

If that indeed transpires, researchers may not be able to repeat an experiment like SHEBA. With sustained warming and stronger westerlies, the ice-albedo feedback could kick in and rapidly rid the Arctic of its white cover during summer. McPhee and his colleagues raised this possibility last year in their paper in GEOPHYSICAL RESEARCH LETTERS. In the title, they asked, "Is perennial sea ice disappearing?"

Early in his career, McPhee would have found such a question unthinkable. Now, he says, "I'm starting to wonder whether we're not going to see it happen." □