OPEN WATER

As the ice melts, fresh obstacles confront Arctic researchers.

BY DANIEL CRESSEY

Last month, US researchers took a 4,000-tonne gamble when they steered the *Marcus G. Langseth* through the Bering Strait and into the Arctic Ocean. The 72-metre research vessel was not built to plow through ice, so it had never ventured that far poleward before.

But the rules are changing quickly in the new north. Managers at the US National Science Foundation (NSF), which owns the ship, decided to send the *Langseth* into the Arctic after reviewing satellite images that showed that the intended survey area in the Chukchi Sea had been largely clear of ice for four of the past five summers.

In an e-mail to *Nature* during the cruise, its principal investigator, Bernard Coakley, said: "We are rolling the dice a bit to take her up north." But the bet paid off for Coakley, a marine geologist at the University of Alaska Fairbanks. Sea-ice coverage was at near-record lows this summer, and the *Langseth* — due back in dock this week — has not encountered any troubling ice.

With the Arctic warming roughly twice as fast as the rest of the globe, there is more need than ever to monitor the changing conditions there. And the retreating summer sea ice is opening up new options for scientists who want to explore the once difficult-to-reach Arctic waters, allowing them, for example, to use vessels other than icebreakers.

But the scientists are not alone. Businesses, too, are racing to exploit the Arctic — for tourism, fishing, transportation and, especially, resources such as hydrocarbons. According to the US Geological Survey, the Arctic could hold up to 30% of the world's undiscovered gas and as much as 13% of its undiscovered oil[1].

Governments keen to access this wealth are stepping up their activities in the area as a prelude to claiming rights to resources in vast swathes of territory under the United Nations Convention on the Law of the Sea (UNCLOS). When Russia planted a flag on the sea bed under the North Pole in 2007, many people saw the action as a symbolic statement about the country's territorial ambitions — a view bolstered this July when Russia pledged to station two brigades permanently in the Arctic. The next month, Canada launched its annual sovereignty operation in the Arctic and claimed that it now had more military capability in the region than ever before.

By some accounts, all this bluster points to a new cold war that could hamper scientists working in the Arctic. But geologists, oceanographers and others who have been conducting research in the region generally see more cooperation than competition.

"What you read in the media is geopolitical conflict," says Hajo Eicken, a sea-ice researcher at the University of Alaska Fairbanks. "What we see is quite the contrary. In many cases, you can do Arctic research only if you have good international collaboration in place."

For researchers, a bigger problem is securing ship time. With the flurry of interest in the Arctic, scientists must compete with drilling companies and others for time on ships designed to operate in the region, which are in short supply. That is how Coakley and his colleagues ended up testing the *Langseth* in the Chukchi Sea.

TERRITORIAL AMBITIONS

When Coakley submitted his proposal to the NSF to investigate the geology of the region, he originally requested the *Healy*, the main US icebreaker, which had been used in past expeditions in the Chukchi. But several factors conspired against that plan, and the *Healy* became overbooked. The icebreaker spent late August and September cruising through the Arctic alongside the Canadian coastguard's icebreaker *Louis S. St-Laurent*. As part of a multi-year project between the two governments, the ships mapped the extended continental shelf off North America to gather information that may help both countries to stake claims to parts of the Arctic sea floor.

AFTER THE ICE
Science at the new Arctic frontier
nature.com/arcticfrontier

US COAST GUARD PHOTO BY PETTY OFFICER PATRICK KELLEY

The icebreakers *Louis S. St-Laurent* (top) and *Healy* are taking part in a multi-year international Arctic survey to map the Arctic continental shelf.

TOP QUESTIONS IN ARCTIC RESEARCH

The Arctic is warming twice as fast the rest of the planet. Here are five issues of particular interest to scientists.

1 ICE

- How are the Greenland ice sheet and other sections of Arctic land ice responding to climatic warming?
- How will the ice respond in the future?
- Are there thresholds beyond which the Greenland ice sheet will become unstable?
- How will melting ice and other freshwater factors alter the Arctic Ocean and the thermohaline circulation that runs through the global ocean basins?

2 AMPLIFICATION

- Why has the Arctic warmed so much faster than the rest of Earth?
- How much of the warming is caused by changes outside the region — such as the influx of heat and pollution from lower latitudes — and how much by local factors, such as regional pollution or feedbacks from the loss of sea ice?
- What is the role of natural variability in the Arctic changes, and how is that likely to evolve?
- How will human activities in the Arctic, such as ship traffic, affect the region?

3 CARBON

- How will changes in the Arctic climate alter the carbon cycle? For example: will melting permafrost release extra methane? Or will the warming boost plant growth, increasing the sequestration of carbon dioxide?

4 ECOSYSTEMS

- How will changes in the Arctic affect ecosystems? This applies not only to the climate but also to shipping, oil and gas drilling, pollution and fishing.
- How well can ecosystems adapt?

5 PEOPLE

- How will Arctic communities, including indigenous peoples, be affected by changes in climate, ecosystems, and the increasing economic activity in the region?

AUTONOMOUS VEHICLES

New eyes for science

Remote and largely ice-bound, the Arctic is one of the world's most difficult places to study. Icebreakers are in short supply and many satellite-borne sensors are unable to peer through the thick clouds that often shroud the region. So researchers are increasingly using autonomous vehicles, such as underwater craft to collect data below the ice and drones that soar above it.

In the past, Arctic researchers relied on relatively unsophisticated tools, such as buoys and sensors that drift on the pack ice. But autonomous vehicles are much more mobile and can collect different data, from sea-ice thickness to bottom topography.

"We're further along than people realize," says James Maslanik, a climate modeller at the University of Colorado, Boulder, who has flown unmanned aerial vehicles, or UAVs, over thousands of kilometres of ocean and ice. The planes are used mainly "to fill in coverage that the big, manned research aircraft are not suitable for", he says.

Maslanik says that teams from Norway, Russia, Denmark and the United Kingdom have conducted polar work with various UAVs, ranging from small 'hobby aircraft' planes fitted with autopilots to high-tech drones such as NASA's Global Hawk.

Researchers are also testing autonomous vehicles that can dive through openings in the ice and then navigate back to the same holes. In 2007, a team from Woods Hole Oceanographic Institution in Massachusetts used a pair of 250-kilogram submersibles to study the sea floor more than 4,000 metres below the surface, where they discovered a previously undocumented form of deep-sea volcanic eruption[4]. Earlier that year, another team used a smaller device to map the underside of the sea ice. **D.C.**

NASA's aerial drone Sierra was used to study sea ice in the Fram Strait.

I. CROCKER, UNIV. COLORADO

Under the UNCLOS, a nation can claim rights to the seabed beyond the usual 200-nautical-mile zone of control — known as an exclusive economic zone — if it can prove that the claimed region is a natural extension of the country's continental shelf. That requires extensive mapping expeditions, which have generated a large amount of work for marine geologists in recent years, but have also sucked up precious icebreaker time.

The United States has not yet ratified the UNCLOS, and signatories have 10 years after they ratify to make formal claims. So it remains unclear exactly what areas might be snapped up in this process. Some projections suggest that the nations bordering the Arctic Ocean will submit claims that cover the vast majority of that region.

Interest in the Arctic extends far beyond its neighbours. China and South Korea, for example, have built large icebreakers to maintain their presence in the north.

Commercial concerns are driving much of the activity in the Arctic Ocean, with oil companies, in particular, jockeying for position. Exxon, for example, beat out BP this summer by signing a multi-billion-dollar agreement with Russian petroleum giant Rosneft to drill jointly in the Kara Sea. Cairn Energy in Edinburgh, UK, is sinking exploratory wells off the west coast of Greenland, and Shell is moving forward with plans to drill in the Chukchi Sea off Alaska next year.

At the same time, tourist ships are increasingly plying the waters off the west coast of Greenland. Between 2000 and 2010, the number of cruise ships visiting the island more than trebled, as did the number of tourists on those ships, according to the Greenland tourism and business council. The north has become a popular destination.

ICE-FREE FUTURE

Opportunities for travel in the Arctic will expand as its sea-ice cover continues to wither. Experts debate how quickly that will happen, because natural variability in the past 10–20 years may have accelerated the disappearance of ice caused by human-induced global warming. So ice loss could slow and ice cover might even rebound for brief periods. "At the end of the day, there's a lot of uncertainty," says Marika Holland, a sea-ice researcher at the National Center for Atmospheric Research in Boulder, Colorado.

But the long-term trend seems clear. "The consensus seems to be that out in the 2030s to 2050s or 2060s is when we might see the loss of all the ice for a short period during the summer," says John Walsh, an atmospheric scientist at the University of Illinois at Urbana–Champaign.

That is likely to lead to a significant rise in traffic in the Arctic Ocean. With the summer sea ice both shrinking in extent and thinning, the region is becoming much more accessible to ice-strengthened ships, which have less formidable protection than true icebreakers. A study conducted by researchers at the University of California, Los Angeles, estimated that by mid-century 23% more of the Arctic's waters will be accessible to vessels capable of just limited icebreaking[2].

Eventually, shipping companies might start to use the Arctic as a short-cut for transporting goods between cities on the Pacific Rim and those bordering the Atlantic. Experimental voyages have been made along the north coast of Russia, and a smattering of ships has crossed the Northwest Passage north of Canada. But don't expect a significant rise in trans-Arctic traffic any time soon. In a 2009 assessment[3], the Arctic Council, an intergovernmental forum for issues affecting the region, projected that most of the shipping in the region will involve bringing supplies to northern communities and exporting resources such as oil and minerals, for at least the next decade and possibly much longer.

"The notion that the Arctic Ocean will become a Panama Canal or a Suez Canal is a figment of the media," says Lawson Brigham, a geographer at the University of Alaska Fairbanks and chairman of the assessment. But, he adds, "there may be a short, summer 'window of opportunity' for trans-Arctic navigation".

These changes are creating a sense of urgency among scientists trying to answer a string of questions about the region (see 'Top questions in Arctic research'). Researchers seeking access to the Arctic Ocean have traditionally relied on icebreakers to get through the ice. But these ships are in short supply in the United States and, to a lesser extent, in Europe, because of lack of investment.

Even ice-strengthened vessels can be difficult for researchers to secure. "Because of the retreat of the sea ice and the oil development we have pending in the Chukchi and Beaufort Seas, a lot of the ice-strengthened vessels are being taken up by industry," says Jacqueline Grebmeier, an Arctic researcher at the University of Maryland in Solomons who has made several trips through the region on the Canadian Coast Guard icebreaker *Sir Wilfrid Laurier*.

Ice-strengthened vessels, meanwhile, are not sturdy enough to provide the kind of access that scientists most desire. "A lot of the processes that are really fundamental to the understanding of how Arctic climate, oceanography and biology work are not happening in summer time," says Lester Lembke-Jene, a marine geologist at the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven, Germany. "If you don't have the full annual observation," he says, "you have a very, very imbalanced and narrow glimpse of what's going on there."

Given the shortage of vessels, researchers are trying to convince others to do some of the work on their behalf. Some commercial ship operators are collecting data for climate scientists, and last year the US government relaunched the Science Ice Exercise, in which military submarines

A researcher ventures off the coast of Alaska to measure tthe thickness of sea ice earlier this summer.

NASA/K. HANSEN

"THE NOTION THAT THE ARTIC OCEAN WILL BECOME A PANAMA CANAL OR A SUEZ CANAL IS A FIGMENT OF THE MEDIA."

collect water samples and measure temperature, salinity, nutrients, chlorophyll and other data for scientists. Researchers are also starting to use autonomous underwater and aerial vehicles to collect data (see 'New eyes for science').

FROZEN OUT

The territorial ambitions of different nations may also end up restricting scientific access. In theory, the areas claimed under the UNCLOS apply only to the sea floor and do not give a country rights over the water above. In practice, however, such claims could hinder scientific work.

"If a coastal state wanted to, it could, by declaring regions to be of special interest for exploration, require that other states request permission to conduct research in the area of the extended continental shelf," says Larry Mayer, a marine geologist at the University of New Hampshire in Durham.

This is more than just idle speculation, he says, because Russia has a history of impeding access to scientists from other nations seeking to work in its waters. Some researchers say that their attempts to put out or collect equipment from areas under Russian control have been thwarted when applications for permits were either denied or went unanswered. The Integrated Ocean Drilling Program, for example, could not obtain permission to drill in Russian parts of the Bering Sea in 2009.

Some scientists familiar with Russia say that the permission problems stem more from the nation's massive bureaucracy than a deliberately obstructionist policy. "Inertia here coming from the Soviet era is really huge," says Igor Polyakov, a Russian Arctic researcher who now works at the University of Alaska Fairbanks. He says that gaining permission for research in Russian waters is much easier now than in the past.

Others report just the opposite. Cheryl Rosa, deputy director of the US Arctic Research Commission in Anchorage, Alaska, says that researchers are still experiencing problems with permits, visas, taxations on funding, getting data out of Russia and other issues.

Despite these concerns with Russia, the view from scientists is that collaborations in the Arctic have never been stronger. The recent International Polar Year, which ran from March 2007 to March 2009, helped by bringing together scientists from different nations to work on dozens of projects in the Arctic, ranging from permafrost studies to research on indigenous peoples. "That's really made a big difference and probably pushed science collaborations further and faster," says Julie Brigham-Grette, a glacial geologist at the University of Massachusetts in Amherst.

Mayer hopes that the Arctic Council or some other body will forge an agreement that will allow researchers continued access across the Arctic. A positive step came in May when the council's eight member states agreed to work together in search and rescue in the region, creating the first legally binding agreement made via the Arctic Council.

Arctic scientists say that the spirit of cooperation is changing their research in profound ways. They are probably ahead of their colleagues elsewhere in terms of releasing information quickly and widely, says Eicken. Data from the NSF's Arctic Observing Network — a system of atmospheric and land- and ocean-based monitoring tools — for example, are made immediately available through an online database so that anyone can access near-real-time readings from the buoys and other observatories.

The advances are motivated in part by the changes in the region. Scientists often take two to three years to process and publish data, but in the Arctic, Eicken says, "that cycle isn't able to keep up with the rapid development".

And if projections are right, scientists will need to work faster than ever to keep up with the unstable conditions. Grebmeier saw just how changeable the region could be in July in her latest trip on the *Sir Wilfrid Laurier*. Several years ago, the ship had run into thick, multiyear ice when cruising near Barrow, Alaska. But this year, the crew found just one bit of ice and even that wasn't terribly impressive. "I was working on the deck — someone yelled 'sea ice'," she says. "I looked up and actually thought taking a picture wasn't worth my time." ■

Daniel Cressey *is a reporter with* Nature *in London. Additional reporting by Richard Monastersky.*

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