Straits of Plenty

The Indonesian Throughflow keeps two oceans talking to each other and influences the fishery that feeds the world's fourth-largest country.

An international research team unravels current patterns where a world-spanning current squeezes through tiny passages

BY ROBERT MONROE

THE YEAR 1999 was not a good one to have business in East Timor.

Yet it was then, at the peak of that country's bloody struggle for independence from Indonesia, that Janet Sprintall found herself on an inflatable speedboat 15 meters (50 feet) from an East Timorese shoreline. On one side of the Scripps Institution of Oceanography researcher was the armed Indonesian Navy vessel that had deposited her there in support of her oceanographic quest. On the other side was a group of agitated East Timorese men rushing down from the hills toward the water. At first Sprintall thought they might be curious farmers wielding rakes. But word crackled over the radio from the ship.

"They were carrying guns," recalls Sprintall, "and there we were with our bright orange vests on."

On the seafloor directly beneath the boat was the pressure sensor Sprintall was there to retrieve. It was an appropriate moment, she thought, to contemplate what she was willing to do in the name of science. Making oneself available for target practice, she decided, wasn't in the job description. The landing party opted to gingerly return to the protection of the Navy ship. As for the sensor, it was on its own.

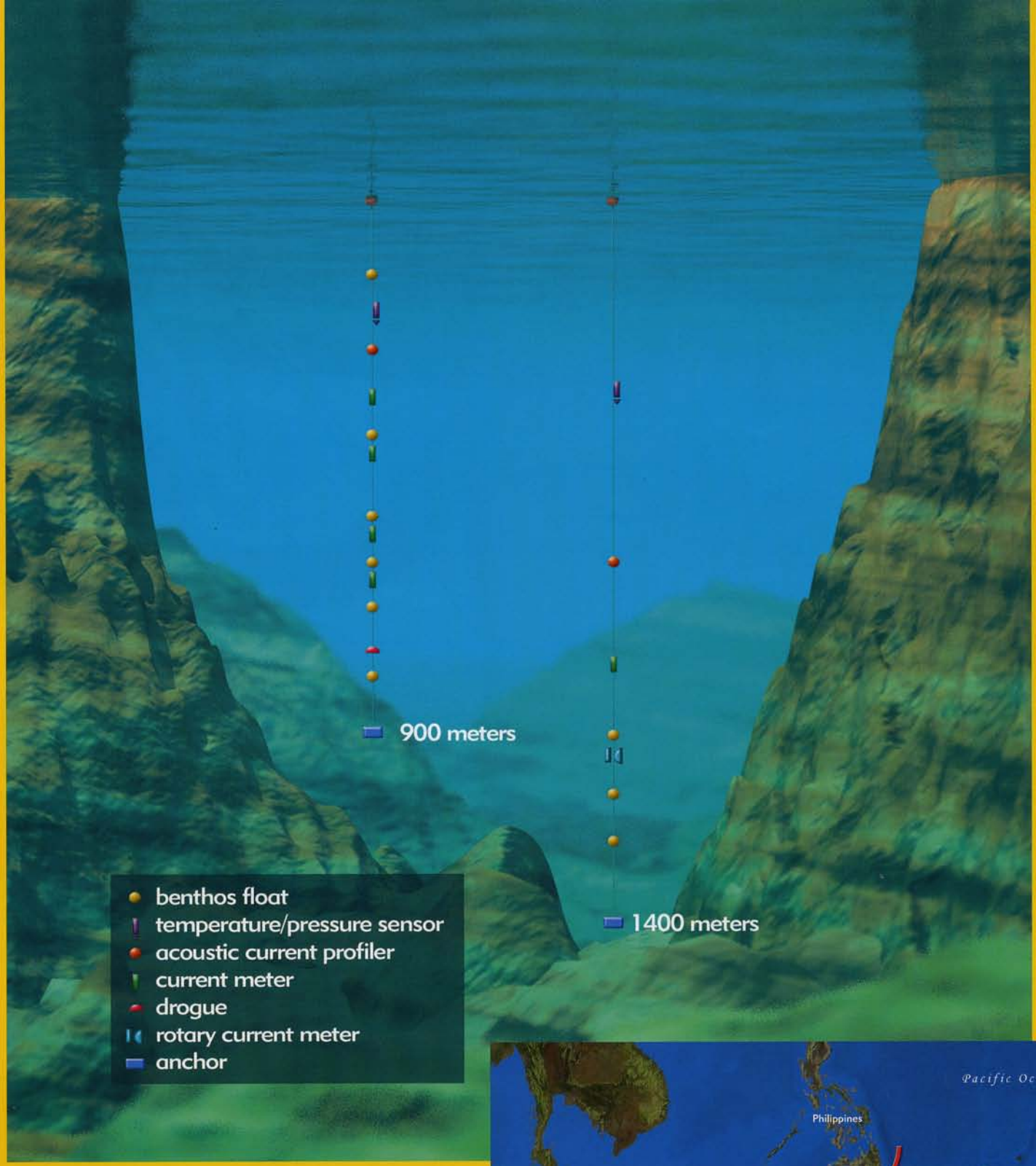
Above, *Clearing a seaweed-coated rotary current meter during INSTANT.* **Opposite**, *Janet Sprintall back at Scripps with a cleaner version.*

In 2003, the physical oceanographer would return to the scene in support of a scientific endeavor that would prove daring in a different way. As a member of INSTANT (International *Nusantara* Stratification and Transport), she is participating in a multinational scientific study of the physical dynamics of Indonesian waters. Project leaders consider INSTANT a feat of logistics—from ship scheduling to customs clearing—that could pave the way for other large-scale studies in a country looking for partners to help develop its oceanographic program.

INSTANT rates as the most comprehensive study ever of the straits of Indonesia, a crucial component in the circulation of the world's oceans as well as a key food source for the world's fourth most populous country. Sprintall is one of several researchers who has studied these waters in piecemeal fashion over the years. Now, along with Arnold L. Gordon of the Lamont-Doherty Earth Observatory of Columbia University and colleagues from Indonesia, Australia, France, and the Netherlands, she is creating a record of what happens as the Pacific Ocean interacts with the Indian Ocean by what is known as the Indonesian Throughflow, a flow of Pacific water that runs into the Indian Ocean 50 times faster than the flow of the Amazon River.

With one phase of the fieldwork now completed, INSTANT's results are already helping to explain and forecast climate events ranging from monsoons to droughts as well as the fluxes of fisheries in Indonesia and surrounding countries.

INSTANT has also given Sprintall a chance to retrieve the sensor she had to abandon in East Timor. She arrived on the same shoreline to find its batteries dead but its data tapes improbably intact. This time



The most comprehensive study ever of the Indonesian Throughflow relied primarily on 11 moorings deployed at key locations in Indonesian waterways, including the Lombok Strait above (circled region in map at right). Tethered to anchors weighing more than 2,500 kilograms (5,511 pounds), instruments attached to mooring lines measured the strength, direction, and origin of current that flows as the Pacific Ocean feeds water to the Indian Ocean. The strait is but one path thermohaline circulation takes through the region.

Components of a mooring were attached and sent off in style aboard the Baruna Jaya.

she came with an official East Timorese observer aboard the ship. She left with no weapons having been brandished.

WATERWAY PILEUP

The Indonesian Throughflow is a hub of a worldwide water flow called thermohaline circulation. The circulation feeds relatively cool, fresh Pacific Ocean water to the Indian Ocean in a bottleneck resembling a busy freeway transition lane. It is here, in the presence of a scramble of fishing fleets, cargo ships, and Navy vessels, that the predominant climate systems of each ocean, the Indian Ocean's Asian–Australian monsoon and the Pacific's El Niño, clash with each other.

"These systems probably affect more people than any other climate feature in the world," Gordon said. "They are really the two most important features of climate variability anywhere, so you really need to understand the Indonesian Throughflow to get it right."

What Gordon wants to get right are the forecast models that simulate world climate. These models require at least an idea of the kinds of energy and heat exchanges that take place at the busy interface. The positioning of Indonesian islands and the complex seafloor bathymetry between them, however, make that a complicated task.

Water from the Pacific wends in a convoluted path starting at the Makassar Strait between the islands of Kalimantan and Sulawesi. Most of the water makes a left turn in the Java Sea to bypass the Indonesian *nusantara*, or archipelago, that includes the islands of Java and Bali. The main flow of circulation then makes a right turn past Timor to enter the Indian Ocean. Smaller spinoff water flows are channeled through the 32-kilometer-wide (20-mile-wide) strait between Bali and Lombok and other smaller passages.

Sequences of counterflows that vary seasonally further nuance the journey. The Java Sea, surrounded by Indonesian islands, acts like a giant turnstile where currents from the Pacific are switched on and off in a giant feedback loop. In summer months, the warm Pacific water sets up the Asian–Australian monsoon season. In winter, runoff from monsoonal rains flows from the islands into the Java Sea and disrupts flow from the Pacific. The feedback drives the throughflow current deeper and weakens it. The obstruction at the sea surface translates to drier weather conditions on land.

On a longer time scale, the process is influenced by climate cycles like El Niño, when the pool of warm water in the western Pacific Ocean shifts toward the east. During El Niño, the supply of warm water passing through the throughflow diminishes. The cooler water inhibits rain, occasionally triggering devastating periods of drought. In 1997–98, Indonesia experienced some of the most devastating forest fires in its history even as El Niño was drenching California.

"Once the warm waters head east, they take the clouds with them," Sprintall said. "It changes Indonesia's fisheries stock. It changes its access to water. It changes the likelihood of forest fires in the country."

GOING WITH THE FLOW

This global mechanism affects more than just the weather in ways researchers are struggling to understand. As the water flows, so too do the myriad fish and invertebrates that support the region's fishing trades. Economically important species such as sardines and mackerel tend to concentrate in the Makassar Strait in spring toward the end of the period in which monsoonal winds blow from the northwest. By September, when the winds have reversed direction and blow surface waters toward the China Sea, the best fishing is in the Java Sea.

INSTANT will help Indonesian fisheries managers understand the links between seasons, current shifts, and fish aggregations. Sprintall and her colleagues deployed their instruments for two 18-month periods. They returned in summer 2005 to collect pressure, temperature, and salinity sensors as well as sonar current profilers that they had launched in 2003. They will return at the end of this year to retrieve the instrument packages that took their place.

Sprintall has already detected unexpected flows. Her portion of the project involved making comparative measurements of temperature, pressure, and currents in the Lombok and Ombai Straits. From instrument-bearing moorings anchored to the seafloor and satellite measurements came a record of water current strength and direction over several seasons. In all, the researchers received simultaneous data from 11 moorings deployed at key locations in the throughflow.

Sifting through preliminary data, Sprintall has discovered that during the northwest monsoon, surface currents, probably pushed by strong winds, created a northward flow of warm, relatively fresh water through Lombok Strait that met the mighty conveyor belt head-on, thus forcing the water to run deeper. She found another against-the-grain eastward current in the Ombai Strait.

Each of these currents introduces a different mix of nutrients, temperatures, and salinity levels to Indonesia's seas, setting off a chain of events through the ocean food web. Details like these are what will allow local fisheries managers to predict trends in fish

The project also required nearshore dives including to the beaches of Ndao Island near Timor, home to a small seashell industry.

Top, *A pair of fishermen regard the Baruna Jaya in the Ombai Strait.*

stocks, making INSTANT data a valuable tool in a region intensively fished by Indonesian and foreign fleets.

"The better prediction of El Niño and La Niña will provide better predictions of rice production and forest fires and will give better understanding of the processes that sustain fisheries stock," said Irsan Soemantri Brodjonegoro, an oceanographer at Bandung Institute of Technology in Indonesia. The technical coordinator for INSTANT, Brodjonegoro said the region's fisheries face their biggest threat from foreign ships fishing Indonesian waters illegally.

Agreements on the part of INSTANT researchers to share data and train Indonesian students helped secure agreement from government officials in the host country. More than 20 researchers joined Sprintall, Gordon, and others last summer on the Indonesian vessel *Baruna Jaya*.

After moorings are retrieved for the last time in December 2006, the INSTANT science team hopes to leave some behind at especially important sites for long-term measurements. Gordon said, however, that the National Science Foundation-subsidized study might end there. NOAA budget cuts would mean only one mooring stands a chance of staying behind, if that.

But the data the INSTANT team has already collected will be a source of analysis for years, said Sprintall. In addition, INSTANT has left its mark on the next generation of Indonesian oceanographers.

"It's important to have scientific collaboration that leads to the benefit of all," said Kandaga Pujiana, an Indonesian INSTANT participant who last year enrolled as a graduate student at Lamont-Doherty. "Mother Nature doesn't recognize boundaries and neither does scientific curiosity."

Above, left and right, *Training a new generation of Indonesian oceanographers, like these cruise participants, was a chief goal of INSTANT.*