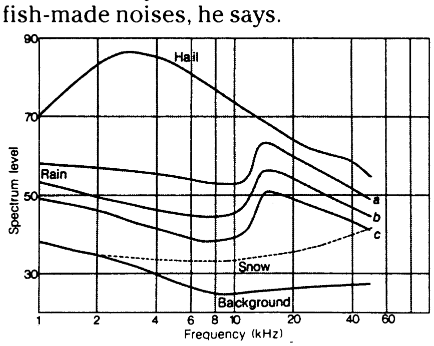
The Underwater Sound of Rain

From deep underwater, amid the rumbles, squeaks, whistles and other noises often heard, researchers are beginning to pick out the distinctive sounds of rain, hail and even snow striking the water's surface. This newly confirmed technique may make it possible to detect and measure rainfall over the oceans, filling a wide gap in knowledge about global weather patterns.

The experiments show that measuring and detecting rain over the oceans using buoy- or bottom-mounted acoustic sensors is, unexpectedly, feasible. Currently, rain gauges on ships provide unreliable, spotty data, and microwave measurements from satellites can't be properly calibrated.

One experiment, reported in the Dec. 19 NATURE, was done in Cowichan Lake on Vancouver Island, British Columbia. There, says Joseph A. Scrimger of Jasco Research, Ltd., in Sidney, British Columbia, "you get as much rain as you'd ever want." In winter and at night, when the measurements were made, the lake is also relatively free of human-made and fish-made noises, he says.



Scrimger/NATURE

Underwater noise spectra for rain, hail and snow at wind speeds greater than 1.5 meters per second. For rain, the upper trace (a) corresponds to the heaviest rainfall, the lower trace (c) to the lightest rainfall.

Scrimger mounted a hydrophone in 35 meters of water about 300 meters from shore. A cable carried the hydrophone's signal to a shore-based instrument, where it was recorded as a spectrum showing how the sound's intensity depends on its frequency. Great care was taken to ensure that the detected signal was truly "the signature of the rain and not of the equipment," he says.

Scrimger managed to observe several rainstorms and, by chance, hail and snow episodes. "We were flabbergasted," he says, "to find that [the rain's signature] was so structured."

Sound spectra for rain, under calm conditions, have a sharp peak at 13.5 kilohertz. Wind tends to round and spread out the peak. Hail, on the other hand, has a broad peak at 3 kHz, while snow tends to get "louder" with increasing frequency. However, these snow sounds are largely at frequencies beyond those detectable by human ears.

Scrimger's results are similar to those obtained by Jeffrey A. Nystuen, now at the Institute of Ocean Sciences in Sidney, British Columbia. While a graduate student at the Scripps Institution of Oceanography in La Jolla, Calif., Nystuen measured rain-generated underwater noise in an Illinois lake, then developed a computer model of a splashing drop to try to explain why the spectral peaks fall at a particular frequency. Nystuen reported his results at a recent American Geophysical Union meeting in San Francisco.

The effect is like that of a "water hammer" banging into the surface, says Nystuen. The impact of large, floppy drops of rain produces a lot of white noise, similar to the buzz heard on a badly tuned radio. Smaller drops produce less white noise.

But an instant after the initial impact, water must begin to flow. For drops of any size, this appears to take about 0.06 millisecond. After this time, no further sound is generated. This means that rainfall spectra should have a peak at close to 15 kHz. Through an earphone, a listener hears a kind of snapping or crackling noise.

"All of the drops contribute to the peak," says Nystuen, "but only the bigger drops cause a rise in the spectral level at low frequencies. That may explain the change in the spectral character from the heavy rain when big drops are present and light rain when small drops are present."

The spectral differences are often quite noticeable. "At Scripps," says Nystuen, "I could look at the spectrum in the lab and tell you what was coming down outside."

Scrimger says he has heard stories about lakes that "sing" when there's a very fine drizzle. These little drops are like explosive charges, he says. "When they hit the surface, they go off with a little ping." In the case of gently drifting snowflakes, the sound is probably generated by a process associated with the melting of snow.

Scientists are already starting to measure the speed of ocean surface winds by detecting their sounds underwater. Rainfall may be next. *— I. Peterson*

FDA may attach strings to artificial heart

Surgeon William DeVries should be allowed to complete the remaining three of the seven artificial heart implants for which he has received permission, but under closer Food and Drug Administration (FDA) oversight, an advisory panel has recommended.

The panel, prompted by generally poor outcomes of the first four implants, met late last month and heard from artificial heart proponents and opponents. Its recommendation, expected to be approved by the FDA commissioner: that the next three implants be allowed on a quarterly basis, with a full FDA review of each one before the next is allowed.

All four recipients of a Jarvik-7 heart from DeVries subsequently had problems with bleeding. Two suffered strokes and one seizures. Only two are still alive, and both of those remain in the hospital.

Surgeons using an artificial heart as a "bridge" while awaiting a donor heart have also encountered problems with strokes and bleeding with the Jarvik-7 and other models.

Mary Lund, the first woman to receive an artificial heart, has thus far avoided the postoperative bleeding and stroke problems, according to a spokesperson at Abbott-Northwestern Hospital in Minneapolis. She came out of a light coma several days after the Dec. 19 implant of a smaller version of a Jarvik-7, and at press time her recovery was going well.

The problems identified by speakers at the recent meeting come at the interface of medical research and human rights. On the one hand, potential artificial heart recipients are dying and the artificial heart may help them or future recipients. On the other hand, critics told the panel, recipients may be the "guinea pigs" of well-intentioned researchers.

George Annas, a professor of health law at Boston University, asked the panel, "If what happened to the first four isn't bad enough [to call a halt to the implants], what is?

"The artificial heart cannot save their lives. It can only change the way that they die."

Among other criticisms leveled at continuation of the procedure: that the review board at Humana Hospital-Audubon in Louisville, Ky., where three of the operations have taken place, has done an insufficient job of oversight; that DeVries's failure to publish what he considers interim data has denied the scientific community the chance for an open evaluation; and that determining when a patient is likely to die and thus in imminent need of an artificial heart is difficult.

In addition, the critics contend, while use of the artificial heart as a bridge until a transplant is available may move a person up on a waiting list, it won't save more lives, since there are fewer donor hearts than are needed. Such a bridge also subjects the person to a second operation.

Proponents note that lives are lost because transplantable hearts are unavailable or a patient does not meet the criteria, based on age and other factors, for the scarce donor hearts. Jarvik-7 inventor Robert Jarvik, of Symbion, Inc., in Salt Lake City, told the panel that roughly 50,000 people in the United States could have their lives extended with an artificial heart.

But, says Annas, "There's nothing scientific or magic about the number seven [implants]. The burden of proof should be on the manufacturer to show why the same results can't be expected in the following three [implants]."

The manufacturer, Symbion, evidently was able to convince the panel during a closed session that planned changes will improve the outcomes. But since the entire application procedure is considered proprietary information and Symbion did not wish to disclose details, the exact nature of the changes remains unknown.

Charles McIntosh of the National Heart, Lung, and Blood Institute in Bethesda, Md., who chaired the panel, said that the changes had to do with postoperative patient management and care, and not modifications to the artificial heart itself. *— J. Silberner*

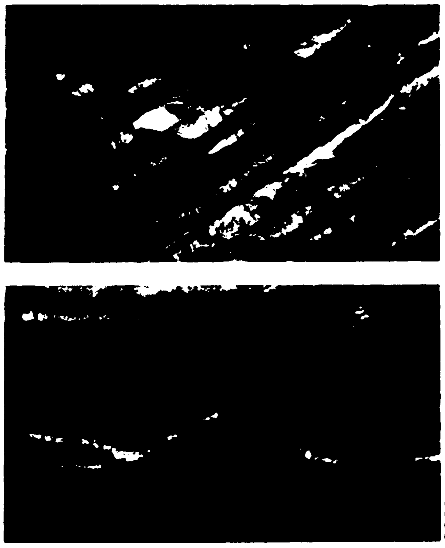
Sonar soundings of the Gulf of Mexico: Sediment on the move

Patterns in sediments, swirling like plumes of smoke, mantle the mudflow fanning out from the Mississippi River. This seafloor scene in the Gulf of Mexico is a sample of the latest batch of sonar images taken by GLORIA, the sidescan sonar system towed by the British research ship *Farnella*. The ship surveyed 140,000 square nautical miles of the gulf last fall as part of the United States' EEZ-SCAN program — a six-year project to map the U.S. Exclusive Economic Zone (EEZ), which extends 200 nautical miles off U.S. shores (SN: 9/21/85, p. 191). The new mosaics of sonar images, processed and compiled by the U.S. Geological Survey (USGS), show that there's a lot more activity on the floor of the Gulf of Mexico than previously suspected.

According to Bonnie McGregor, a Reston, Va.-based USGS marine geologist and project chief of the Gulf of Mexico cruises, the swirls of sediments in the Mississippi fan probably resulted from underwater landslides, which she says cover a much larger area than scientists had thought. She suspects that these landslides are generated during times of low sea level, when rivers like the Mississippi deposit piles of mud far out to the edge of the continental shelf. Then the breaking of ocean waves at the shelf edge jars the piles, causing them to collapse and slide down the steeper continental slope. McGregor would like to test this idea by seeing if landslides in two coastal gulf areas to the east and west occurred at the same times as those in the Mississippi fan.

The recent sonar images indicate that river channels are not the only means of carrying sediments to the fan. "Submarine landslides are also an important process in transporting sediments in the deep ocean," says McGregor. Scientists are especially interested in studying these processes on the Mississippi fan, she adds, as part of an effort to make a model for oil exploration in ancient fans on land.

The recent survey of the gulf also produced images of the continental slope off the coasts of Texas and Louisiana. The slope is being extensively deformed by a mass of salt diapirs, or rising domes, which is wedging itself


USGS

Sonar mosaics of the Gulf of Mexico. Top, the swirls in the mud of the Mississippi fan resulted from underwater landslides and extend over a much larger area than scientists had expected. In the lower left of this mosaic is a meandering channel, cut into the mud by the flow of water and sediments from the Mississippi. In the bottom mosaic, the light image of the Sigsbee escarpment, a step in the continental slope off of Texas and Louisiana, snakes left to right. This escarpment marks the edge of a mass of salt domes that flowed down the slope as they pried their way between mud layers. The vertical channel in the image, now plugged by the salt, may have served as drainage for the Mississippi at one time. Because the channel is still visible, scientists conclude that it was active in the recent geologic past. Both mosaics span areas of 40×80 nautical miles. The "tiger stripes" in the images are the areas just under the sidescan sonar system, called GLORIA, which is towed behind a boat. Light regions represent materials that reflect sonar energy well, such as sandy or well-consolidated muds.

between layers of mud as it flows downslope. At the edge of the salt mass is a 700-meter step called the Sigsbee escarpment. The EEZ-SCAN images reveal that sediment is able to move across this escarpment, forming piles of debris on its seaward side. And engraved in these sediments are wavelike bedforms, indicating to McGregor that "water currents in the gulf are being channeled along the escarpment, reworking the sediments on the seafloor."

On the eastern side of the gulf, the researchers obtained images of the west Florida escarpment, the edge of the carbonate platform that forms Florida. The images reveal an extensive network of channels that have been eroded into the escarpment edge. According to McGregor, these channels vary in shape and depth along the length of the escarpment. Her group is now studying the images in detail to try to understand the processes that form the channels and how these processes differ at different latitudes. Getting these kinds of images with conventional sonar techniques, which look straight down on the ocean bottom, has been difficult because of the steepness of the escarpment, says McGregor. "The sidescan images [which look at a broad swath, 22 km to either side of the ship] for the first time show us clearly what the topography of the steep escarpment is," she observes. "Now we can look at the escarpment as a total unit."

The main advantage of the GLORIA sidescan system is that it can cover large areas very quickly; last summer it surveyed 250,000 square nautical miles off the coasts of Oregon, California and Washington in 100 days and at a cost of about 1¢ per acre. According to McGregor, the British are now building another GLORIA system, which the United States will lease or buy. Scientists hope the system will be completed by the time the *Farnella*, which returned to the United Kingdom for maintenance after surveying the EEZ around Puerto Rico, returns early this year to survey the waters around Alaska and Hawaii. *— S. Weisburd*