And Into the Warming Sea Rode the 4,000

A vast, international shock force of weather researchers shoulders its instruments to confront the mysteries of the tropics

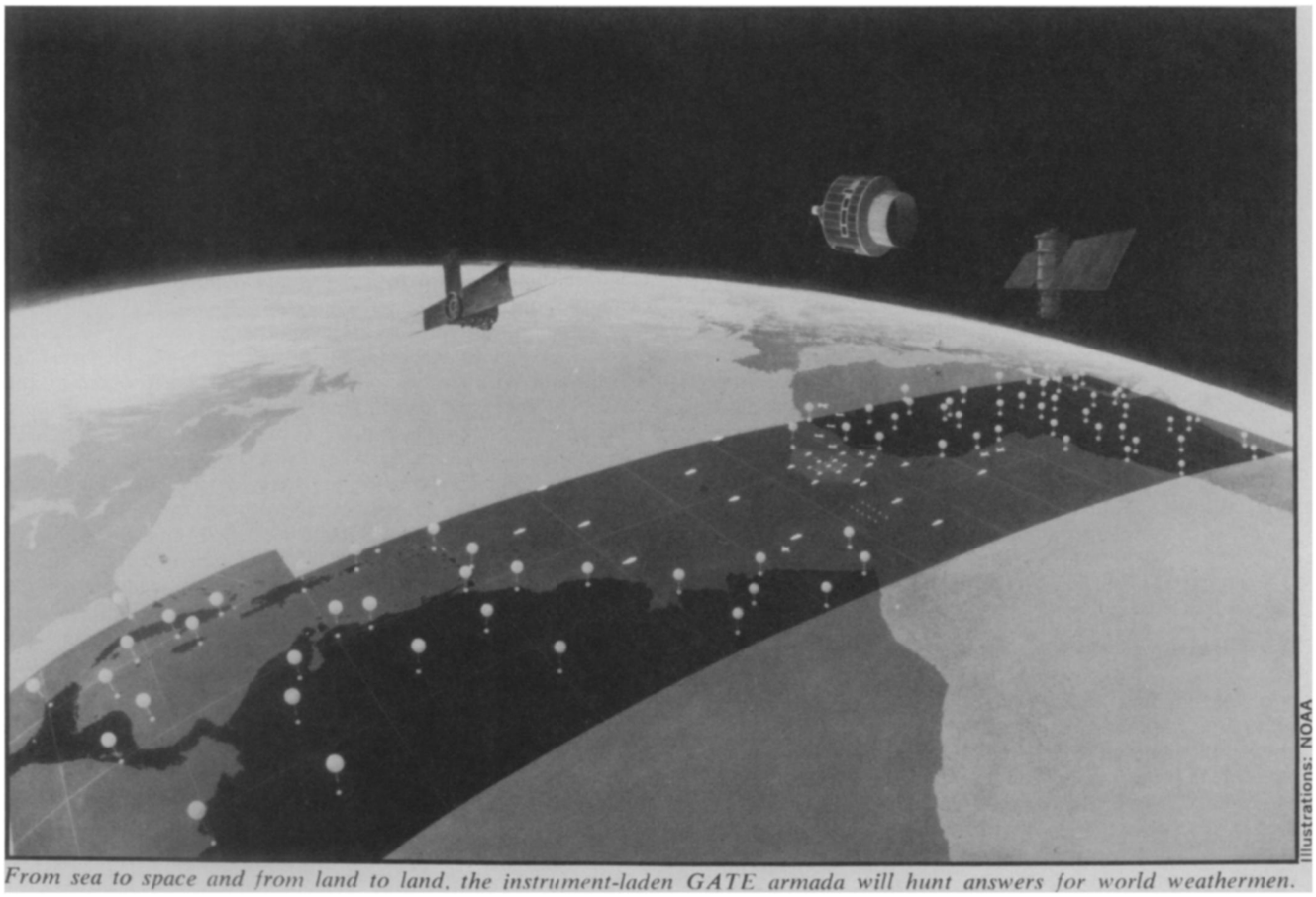
by Jonathan Eberhart

Dakar, capital of Senegal, confronts the ocean from the westernmost part of Africa's Atlantic coastline. Scarcely revered as a world center of research, it is nonetheless the hub of what is surely the largest and most complex scientific experiment ever performed: the GARP (Global Atmospheric Research Program) Atlantic Tropical Experiment, known as GATE.

The tropics, as Verner Suomi of the University of Wisconsin, chairman of the U.S. GARP committee, puts it, are the "weak link" in everyone's weather data banks. Half of all the sunlight reaching the earth falls there, and they are the only region of the globe which receives more solar energy than it radiates away to space. The tropics are the driving force behind the great "heat engine" which runs the world's weather, yet considering their importance, appallingly little is known about how they work.

Finding the answers to such a global question is in every way a global problem. No single nation could hope to marshall the resources necessary to even approach a solution. The result, after five years of planning, budgeting, research and diplomacy, is GATE, a giant by any measure.

The 14 weeks, from June 15 to Sept. 23, that will be devoted to constant, coordinated data-gathering for GATE will demand the services of some 4,000 people from as many as 72 countries, probing a 20-million-square-mile swath of the globe from a mile below the ocean surface to the top of the atmosphere. Their electronic eyes and ears will be carried aboard 38 ships, about 65 buoys, 13 aircraft and six kinds of satellites, stage-managed every step of the way with the aid of an incredible



Illustrations: NOAA

From sea to space and from land to land, the instrument-laden GATE armada will hunt answers for world weathermen.

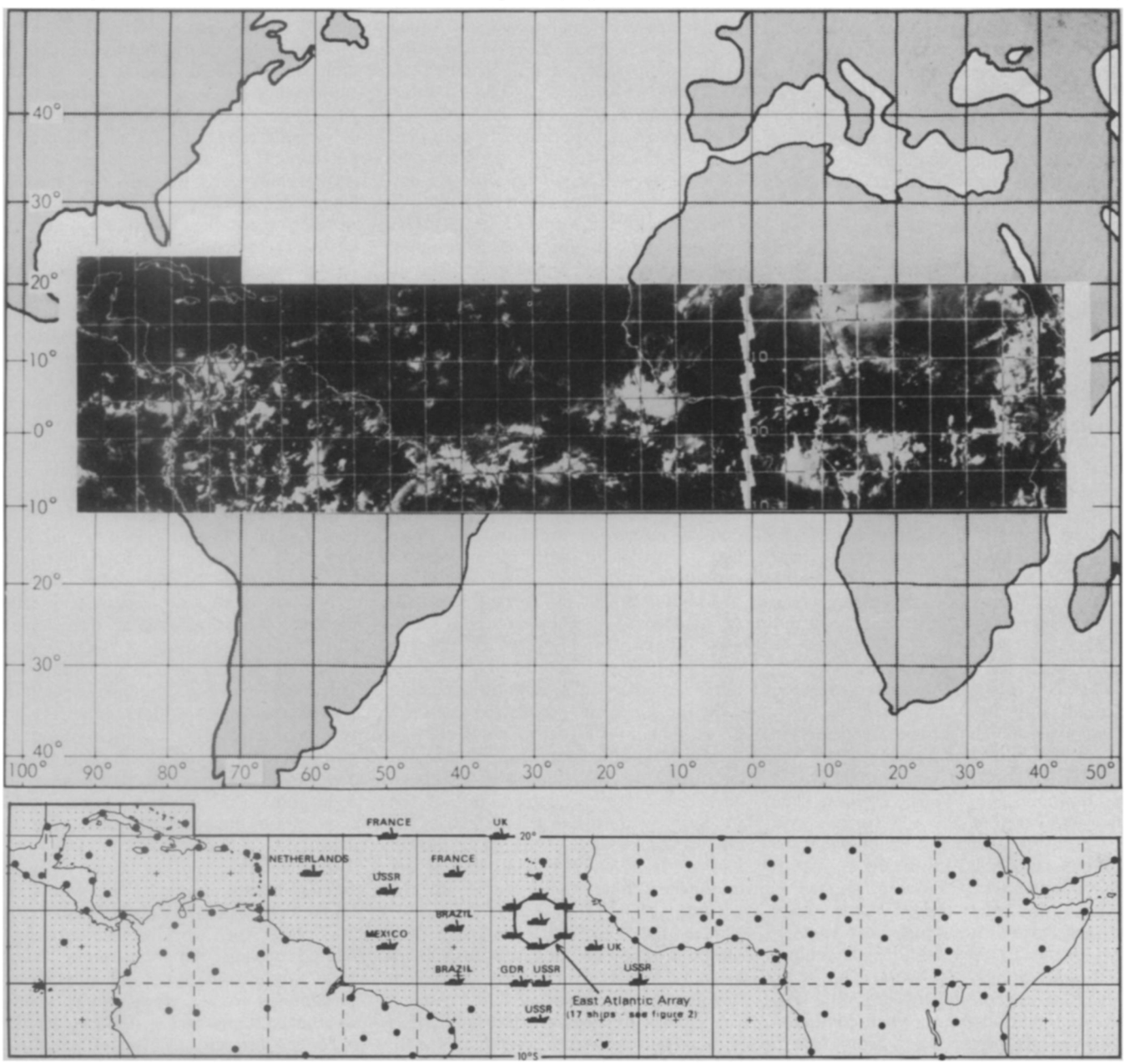
array of guidebooks, operations manuals, flow charts and communications guides designed to stave off what would otherwise be looming chaos. "It's going to go fine," says an official involved with coordinating the aircraft, "but man, it sure would have been a mess without all the planning."

The goal of all the planning is to build up a unified, manageable picture of just what goes on in the tropics. Oceanographers and meteorologists have only a general idea. Much of the excess solar heat falling on the tropics is stored in the tropical oceans. About a third of the ocean heat load is believed to be carried to higher latitudes by ocean currents, while the rest is transferred back into the air, largely through evaporation of the water. The warm, moisture-laden air rises to where lower temperatures and reduced atmospheric pressure let the water condense, to be picked up by the elaborate patterns of high-altitude winds that blanket the globe. Depending on the movements of the air, the condensing water can form gentle, individual cumulus clouds, cloud clusters or even towering pillars of cloud revealing almost the entire domain of a vertical convective system. Or the results can be less than gentle—tropical storms, ranging from little squalls to powerful tornadoes to vast hurricanes.

The overriding reason for GATE, however, is that the effects of tropical convection are not confined to the tropics. Air moving in the tropics pushes around air elsewhere; moisture blown north and south from the equatorial regions may become trapped in convective cycles thousands of miles away.

Meteorologists trying to forecast tomorrow's weather, or next week's, have little use for such a broad picture. As the state of daily weather prediction attests, they need more detail. They must either have measurements from a far greater number of locations, or find out what kinds of sampling will enable them to generalize about the regions that are not covered. At present, the sophisticated mathematical modeling that leads to predictions is well equipped with information about the middle latitudes, but the inaccuracies show that generalization about the rest of the world weather system is a shaky proposition at best. Accurate predictions are limited to a day or two because of, among other things, all those pesky unknowns that keep blowing out from the tropics. Ergo, GATE, with its incalculable miles of data.

Data are at the heart of the matter,



The East Atlantic Array will focus dense instrumentation in an area known for its numbers of convective cloud systems.

and not only to fill the gaping craws of the meteorologists' computers. An equally important goal, says Joachim Kuettner, director of the GATE International Scientific and Management Group, is to make tenable what he calls a whole new avenue of research: cooperative programs that can handle problems too big for a single country, yet produce results in a useful form.

It would be easy simply to commandeer every ship and plane in sight, pack them with instruments from bulkhead to bulkhead and accumulate a few thousand miles of computer tape full of numbers. But who could use the data? Everything would be buried in such a proliferation of measurements that the tapes would probably end up collecting dust in a few hundred dark closets.

If that happens, says one GATE oceanographer, GATE will have been a flop. The running GATE joke, says Douglas Sargeant, head of the U.S. GATE office, is that "paper is our most important product." Project officials remember a bitter lesson taught by BOMEX, the Barbados Oceanographic and Meteorological Experiment, a 1969 study of air-sea interaction conducted back when GATE was just a thinnish book of recommendations. "The biggest thing they learned," says Eugene Bierly, in charge of GARP at the National Science Foundation, "was that the data management problem, once the experiment was over, was horrendous." There were problems with science, problems with software, even problems with contracts. "It has literally taken years to get the BOMEX data in usable form to the scientists," Bierly says. "And I mean years." Five years after it was collected, in fact, the stuff is still trickling out.

GATE planners have done everything they can think of to be sure the data will be not only available, but meaningful. "Otherwise," says one, "the whole thing will just be fun and games."

To keep the mountain of numbers under control, the GATE data will be divided into five categories, each of them entrusted to a separate center in a different country. Reading from the geophysical bottom upward, they are:

Oceanography: Brest, France. The characteristics of the sea surface and the transfer of energy from water to air will be studied by means of instruments suspended from ships as well as carried in other ways. Data from BOMEX, tardy though it was, enabled this phase of GATE to be kept simple.

Boundary layer: Hamburg, Germany. The behavior of the lowest 2,000 meters of the atmosphere, when combined with the sea-surface data from below, may turn out to be the major contribution in learning what controls the amounts of heat and moisture reaching up to the clouds.

Convection: Washington, D.C. A detailed look at the effects of convection will include following the life cycles of individual clouds and cloud clusters, as well as watching how the clouds are affected by specific phenomena such as the Intertropical Convergence Zone (an often cloudy belt north of the equator where the northeast and southeast tradewinds meet, whose day-to-day variations may hold clues to atmospheric circulation and temperature changes). Aircraft, balloons and dropsondes will aide in this branch of the study, including an investigation of the recently discovered tropical atmospheric waves, which Suomi believes may be some kind of trigger that releases the rising heat into the atmosphere.

Synoptic-scale: Bracknell, England. This will be the large-scale study, with all its measurements spaced and timed accordingly (as are those in the other sections) to look at long-distance effects and broad patterns. The synoptic-scale team will also provide information during the experiment to help plan daily operations for the GATE ships and aircraft, as well as to lay out strategy in exploring smaller cloud systems.

Radiation: Leningrad, U.S.S.R. This will be a continuation of an experiment run last year by Soviet scientists, to study the balance between incoming and outgoing energy at the top of the atmosphere. Like the earlier experiment, it will concentrate on a small sample area, ringed at the ocean surface by six Soviet research ships and extending upward via aircraft and satellite measurements. The earlier study also revealed some communications difficulties between ships on station and the control center at Dakar, one of numerous problems that have had to be dealt with during GATE's evolution.

Another Soviet study that has contributed to GATE is CAENEX, the Complete Atmospheric ENergetics EXperiment, a related investigation of how much of the sun's radiation reaches different parts of the earth's surface. Phase one, in 1970, was conducted in the Kara Kum Desert; phase two a year later, was on the steppes of northern Kazakhstan, followed by a test of the influence of an urban heat island at the city of Zaporozhye. With GATE, Soviet CAENEX researchers will be able to expand their land-bound studies to the ocean.

Much of GATE will take place over land, in fact—the test site runs from eastern Africa all the way across to beyond the west coast of South America—thanks to almost 1,000 land-based stations of the World Weather Watch. But the phenomenon of Africa's sub-Saharan drought suggests that more land measurements could well have been included. Such an effort, called the Continental African Program, or CAP, was discussed, but the heaviest part of the drought came too late to help inspire necessary funding for what would have been an additional $1.5 million. "The biggest mistake we've made in GARP," says Bierly, "is probably failing to do CAP."

GATE has always been a predominately over-ocean program, although it was not originally intended for the Atlantic. A 1969 study by the National Academy of Sciences envisioned it as a Pacific program, but planners were stymied when confronted with the fact that the only eligible Pacific site for the control center (which requires a deep-water port and a large jet airstrip) was in the Marshall Islands—part of the U.S. Pacific Missile Test Range and hard to reach from the mainland. It was then moved to the western Atlantic (which has a compensation in that it makes the BOMEX data from the Barbados area more directly applicable), only to be faced with extreme reluctance by the Soviet Union, a necessary participant, to take part unless it were further moved to the eastern Atlantic. Thus, Dakar.

Once GATE has enabled meteorologists to expand their mathematical models to include the tropical Atlantic, they will try their new Atlantic-derived theories on the Pacific, to see if they have yet earned the right to generalize about what makes the tropics work. To give them a slight head start, GATE will gather a little Pacific data from Indonesia, French Polynesia and Singapore while the Atlantic experiment is in progress. With luck, the scientists will find that they can apply their techniques around the globe; otherwise, says Bierly, a Pacific GATE would still not be a bad idea—though it might still be an unlikely one.

Beyond GATE, the researchers face the awesome prospect of an even larger effort. FGGE (pronounced "figgy"), the First GARP Global Experiment, is scheduled to girdle the planet with a year and a half of data gathering in 1978 and 1979. In the most monumental coordinated study of all time, it will divide the entire globe, from pole to pole, into 500-kilometer squares, and take measurements from every one of them.

The overall goal of GARP sounds, and is, monumental. In the words of NOAA Administrator Robert White, it is "to place the world's weather, and related oceanic variables, under complete surveillance." A tall order, yet so complex are the world's interlocking weather systems that it is necessary, in order to stretch accurate predictions from a few days to even as little as a week. □