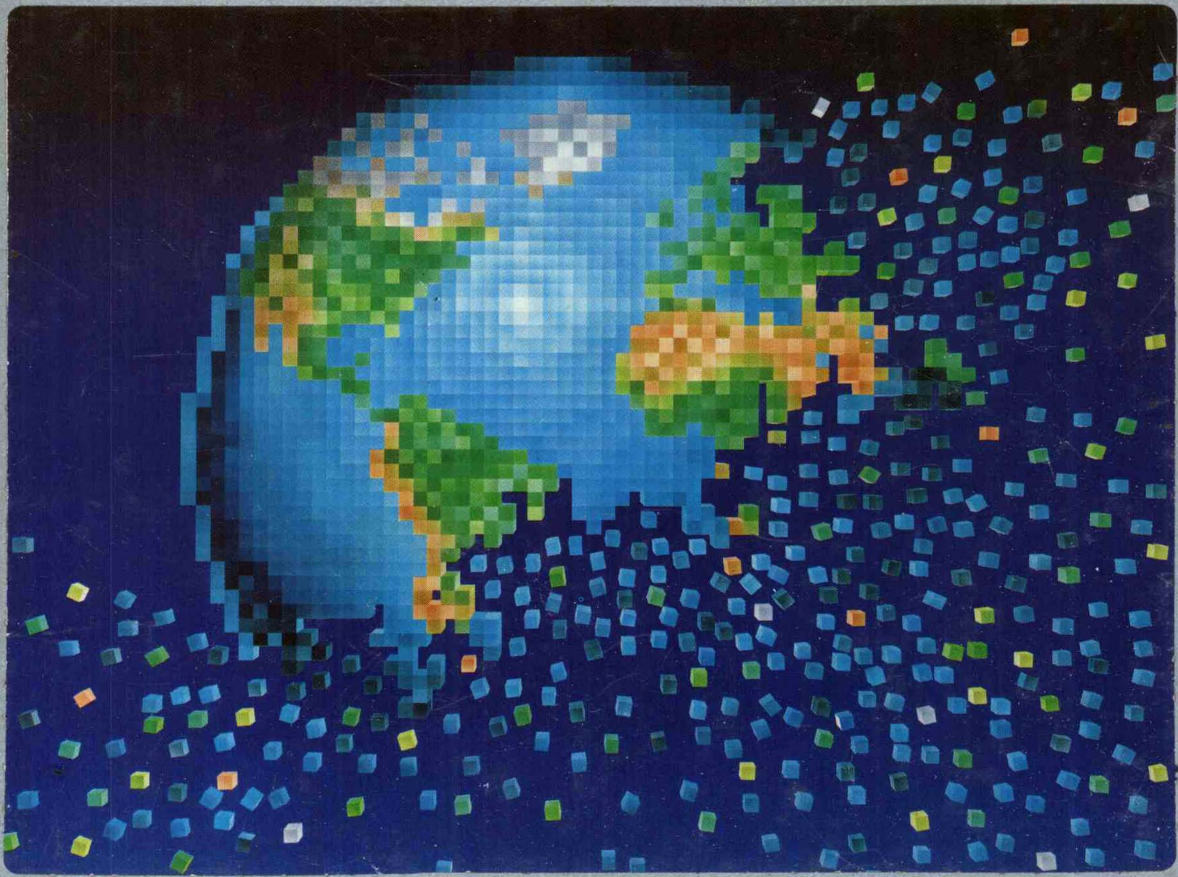

The Puzzle Master

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This volume is one of a series that examines various aspects of computer technology and the role computers play in modern life.

UNDERSTANDING COMPUTERS

The Puzzle Master

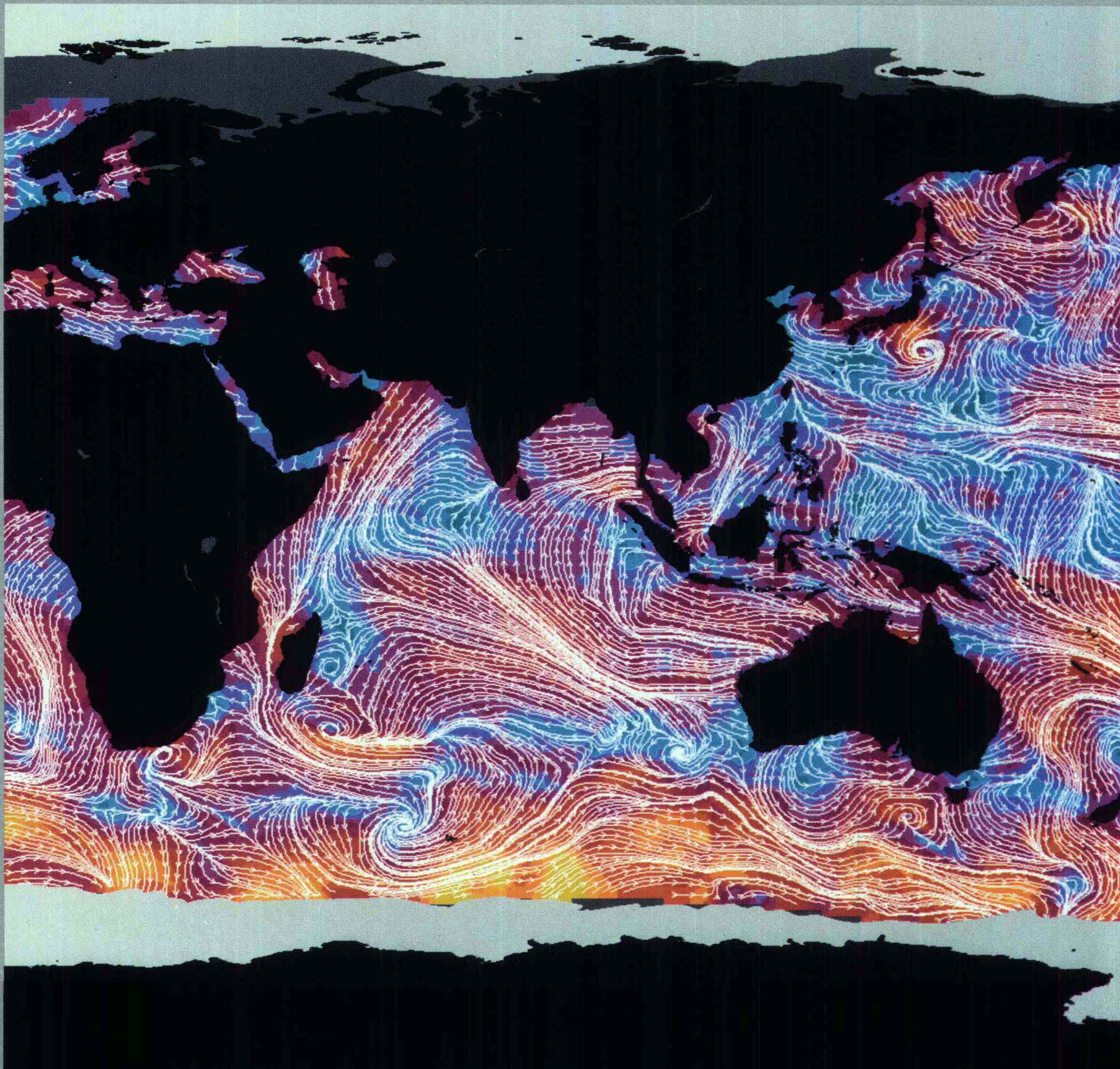
BY THE EDITORS OF TIME-LIFE BOOKS
TIME-LIFE BOOKS, ALEXANDRIA, VIRGINIA

Contents

Painting Nature by the Numbers

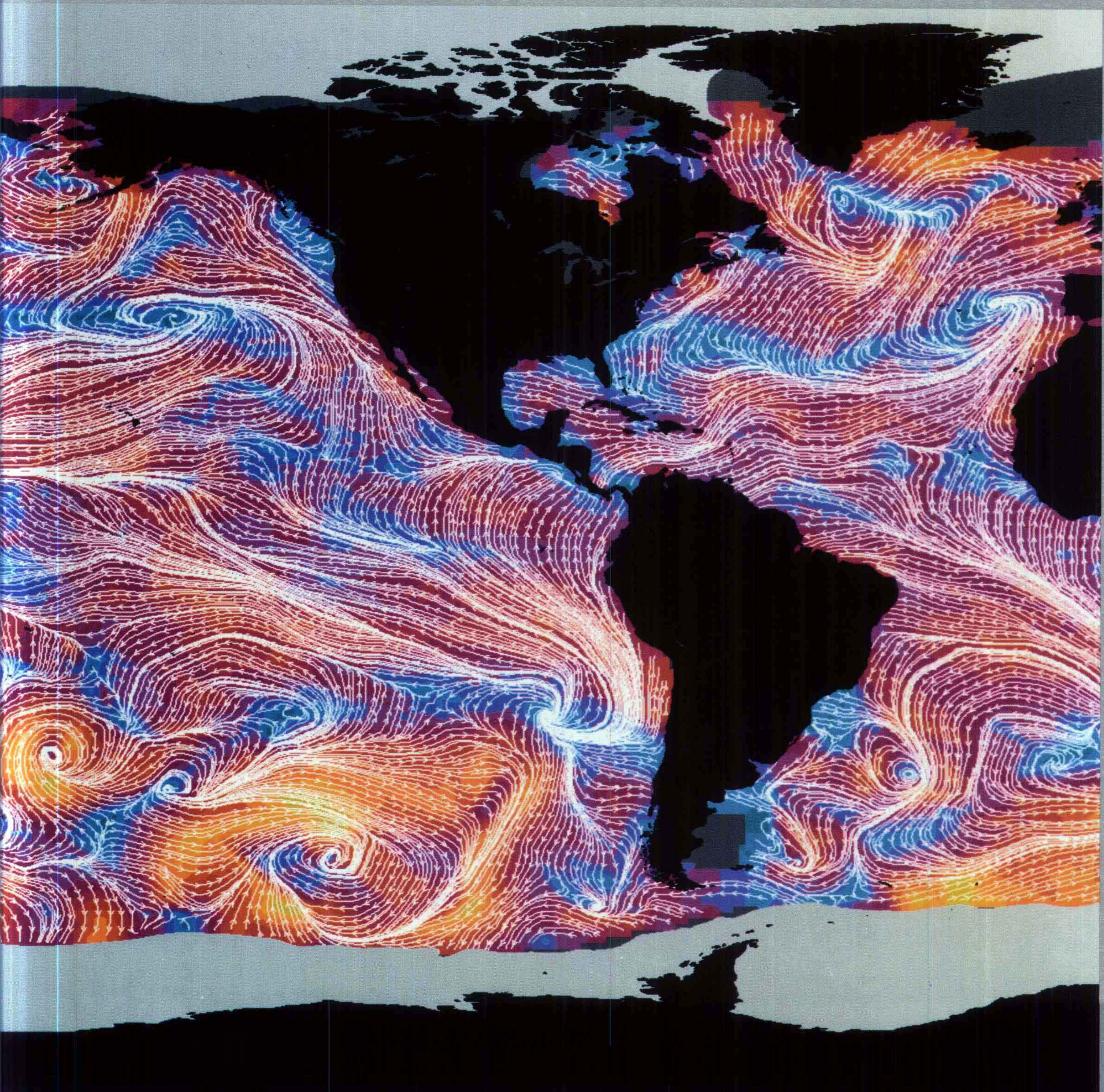
The modern tools of scientific inquiry provide an almost overwhelming amount of information on a wide range of subjects. Sophisticated instruments detect and measure everything from ozone in the Earth's atmosphere to the magnetic field of Uranus, filling computer memories with countless billions of bits of data. The computer, which is so essential in the collecting, storing, and analyzing of that information, also plays a significant role in making the information easier to comprehend. As demonstrated here and on the following pages, computers are frequently used to express facts and figures visually, translating huge masses of data into portraits that can be read at a glance.

The highly detailed image of oceanic wind patterns below



began with raw data from NASA's *SEASAT*, an orbiting satellite that bounced radar beams off the ocean surface and then measured how tiny wavelets driven by surface winds scattered the reflected beams. A computer program processed these measurements through complex formulas to determine both wind speed and direction. The millions of numbers that resulted meant little until graphics software turned them into lines and colors, allowing oceanographers and meteorologists to see patterns that might otherwise have remained buried in digital obscurity.

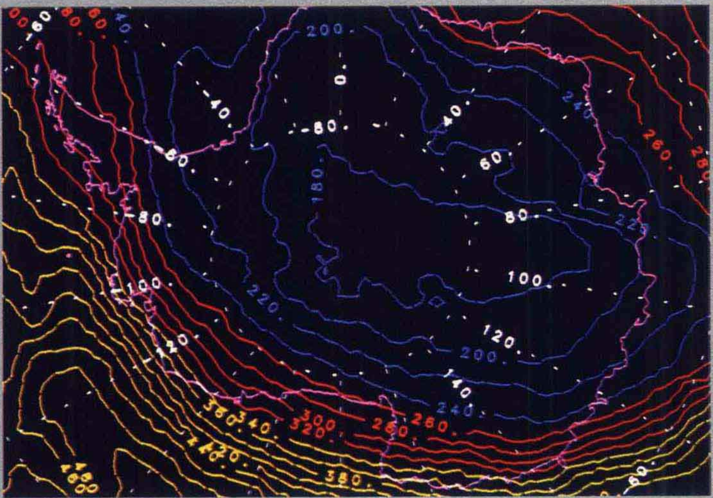
Mapping ocean winds. This computer-generated image of ocean wind patterns is based on more than 150,000 surface-wind measurements made by satellite-borne radar during a single day. White lines with arrows indicate the direction of wind flow, and colors denote wind speed, with blue for the lowest speeds and yellow for the highest. Swirling patterns that curve counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere identify storm systems.

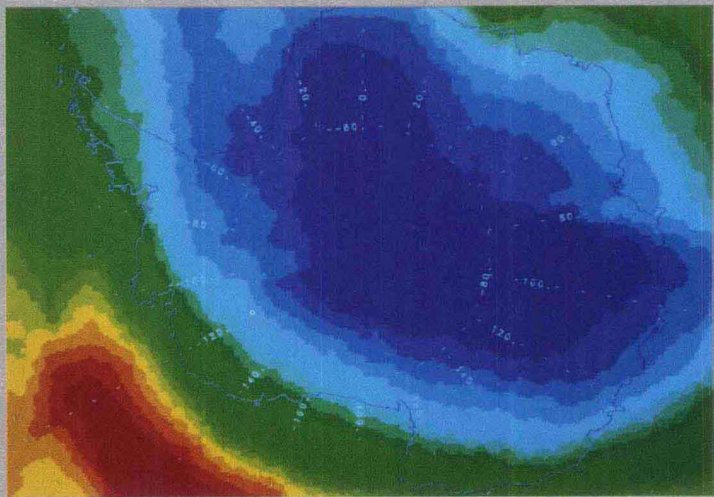


Uncovering a Hole in the Ozone

Depletion of atmospheric ozone, believed to be caused by the release of chemical compounds known as chlorofluorocarbons, represents a potentially serious threat to life on Earth. Without an ozone shield, plants and animals—including humans—would be exposed to dangerously high levels of ultraviolet radiation from the Sun. In the 1970s, scientists began collecting data on ozone levels worldwide from the ground, air, and space. Some observations indicated that the ozone level was unusually low during the spring in the South Polar region, and satellite readings confirmed the findings. But the problem did not really go public until the mid-1980s, when computer-imaging techniques brought the evidence before the world's eyes.

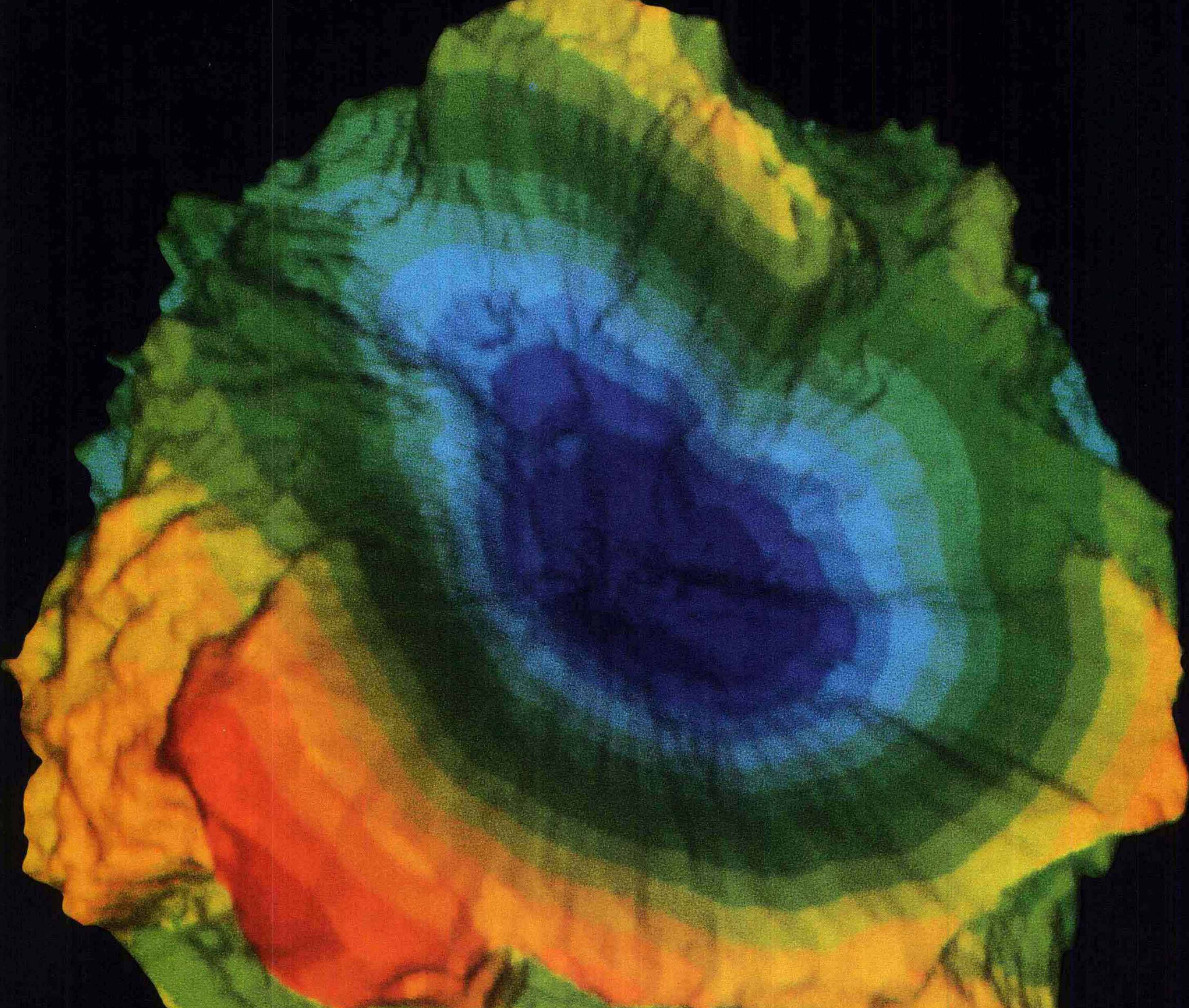
The data for images came from a satellite equipped with a sensing instrument called a spectrometer, specially attuned to detect the wavelengths of sunlight that pass through ozone in the upper atmosphere as they reflect off dust particles, clouds, and the Earth's surface. The spectrometer rated the brightness of the reflected light on a scale ranging from 0 to 255, taking almost 200,000 separate measurements daily around the globe. Ground-based computers then used the brightness values to calculate the amount of ozone at each location where measurements were taken. By plugging these figures into graphics-generating software, scientists were able to create several different visual versions of the data to aid in the task of analyzing this complex phenomenon.





Two methods of mapping. Shown on this page are two basic visualization techniques for representing the thickness of the ozone layer over Antarctica, outlined above in pink and at right in blue. The contour lines above delineate differing levels in Dobson units, where one unit is equivalent to a layer of ozone one-thousandth of a centimeter thick; yellow lines denote above-average levels, red lines average, and blue lines lower than average. The image at right uses additional colors and shades to emphasize the variations, this time with red signifying the highest levels.

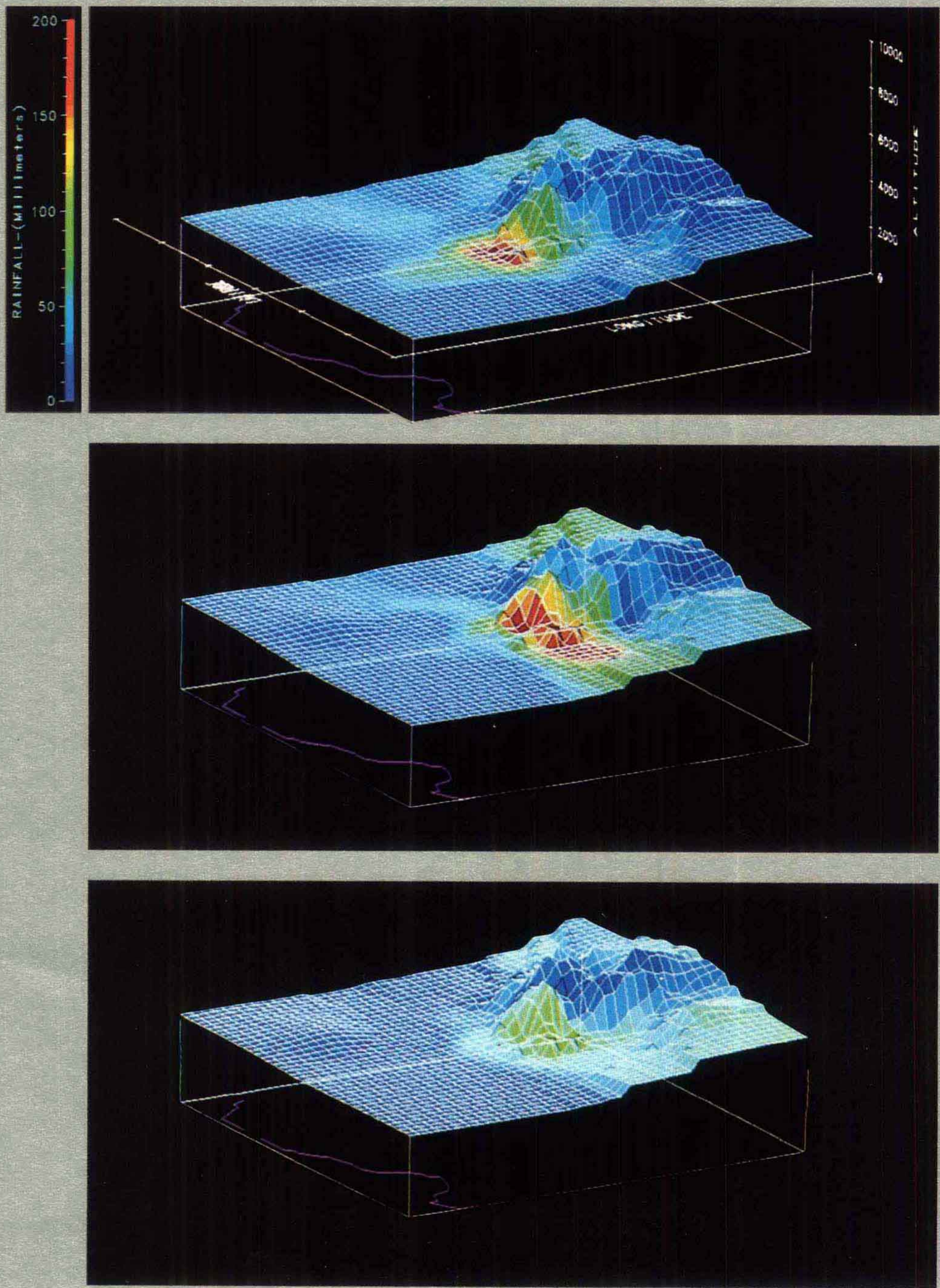
A three-dimensional view. By translating ozone measurements into both color and height, the image at right clearly demonstrates the concept of a hole in the ozone above the South Pole. High ozone levels appear as red and yellow peaks, which drop off in green and then light blue slopes to the dark blue depression in the center that represents the thinnest region of ozone. Sophisticated graphics software is necessary to create the proper shading that gives the image a three-dimensional appearance. ▶



Charting the Course of a Deadly Storm

In many regions of the world, rainy and dry seasons occur with such clockwork regularity that science can add little to traditional knowledge of when and where rain will fall. But occasionally along the west coast of South America, changes in ocean currents and trade winds—known as El Niño events because they tend to arrive near Christmas—create havoc with local climates: Storms dump immense quantities of rain on areas unaccustomed to more than a few inches per year, bursting dams, washing away houses, and causing great loss

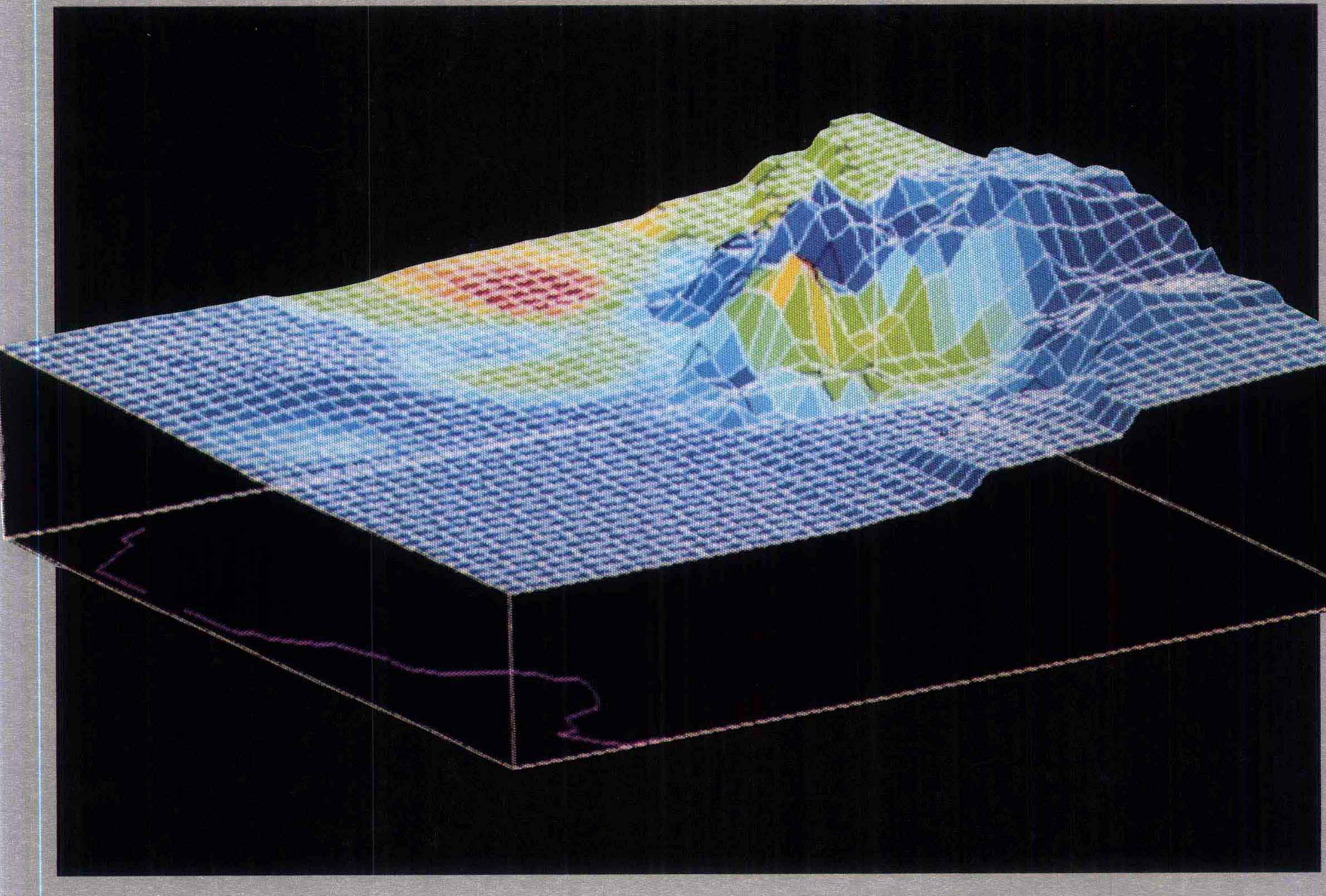
A rainstorm's progress. The sequence of computer-generated images at right illustrates the pattern of rainfall in northwestern Peru during a three-day period in January 1983. A three-dimensional grid portrays the local topography, with altitude in meters; the Pacific coast is outlined in pink below the grid. A color scale *(near right)* represents the daily rainfall in millimeters, ranging from 0 *(blue)* to 200 *(red)*. On the first day *(top)*, heavy rain falls inland as the storm breaks against the Andean foothills. Cold air sweeping down from the high Andes intensifies the precipitation on the second day *(middle)*. By the third day *(bottom)*, the storm has slackened somewhat but will regain its strength as it continues to interact with the mountains.



of life. Computer visualizations have proved useful in helping meteorologists understand the unusual weather patterns that characterize these events.

The study illustrated on these pages made use of data gathered from sixty-six weather stations scattered throughout northwestern Peru. A computer compiled rainfall measurements from each of the stations and, in order to create a continuous pattern of rainfall over the region, extrapolated measurements for the areas lying between stations. All this information was then displayed graphically on a computer simulation of the landscape.

A sequence of images for several consecutive days reveals the initial eastward course of a storm and its recoil off the mountains and back to the customarily dry plains that lie along the seacoast. Such animated views clearly demonstrate the significant effect that local topography can have on the development and direction of a storm and where it will unleash its greatest fury.



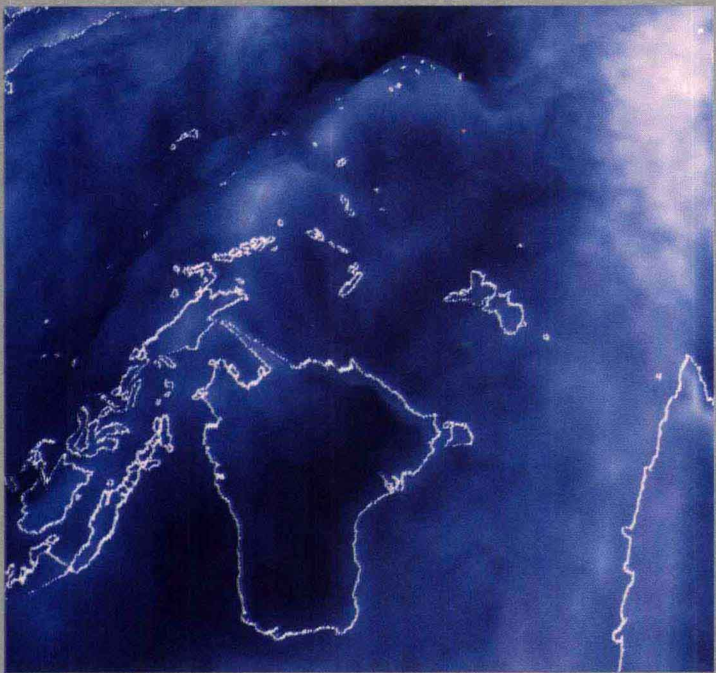
The final deluge. By day four, the heart of the storm system has shifted to the northwest, in effect having rebounded off the mountains and back toward the coast with renewed vigor. The intense rainfall denoted by the red patch occurred over a very short time and caused devastating floods and mud slides on the normally arid coastal plain.

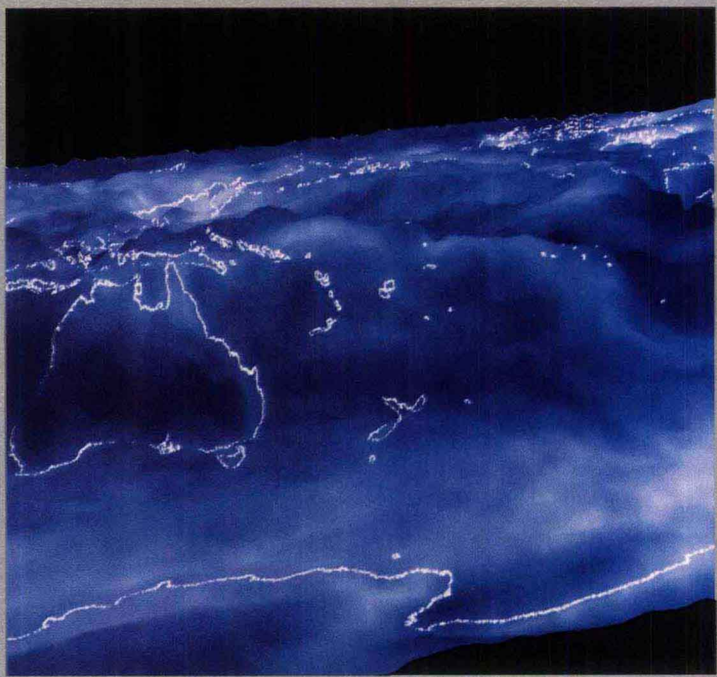
Computerized Views of the Clouds

Any study of the Earth's climate must take into account the crucial role played by clouds. Besides delivering life-giving rain to the land, clouds help maintain a proper balance in the global climate: As the Sun heats bodies of water and landmasses, clouds build up and block some of the solar radiation, allowing the surface to cool; when the clouds subside, the Sun gets through again and the process begins anew. The varied features of the Earth's surface, as well as the prevailing patterns of the wind, greatly influence the formation and distribution of clouds. Computer graphics that allow scientists to visualize these effects have provided important insights into the dynamics of global weather systems.

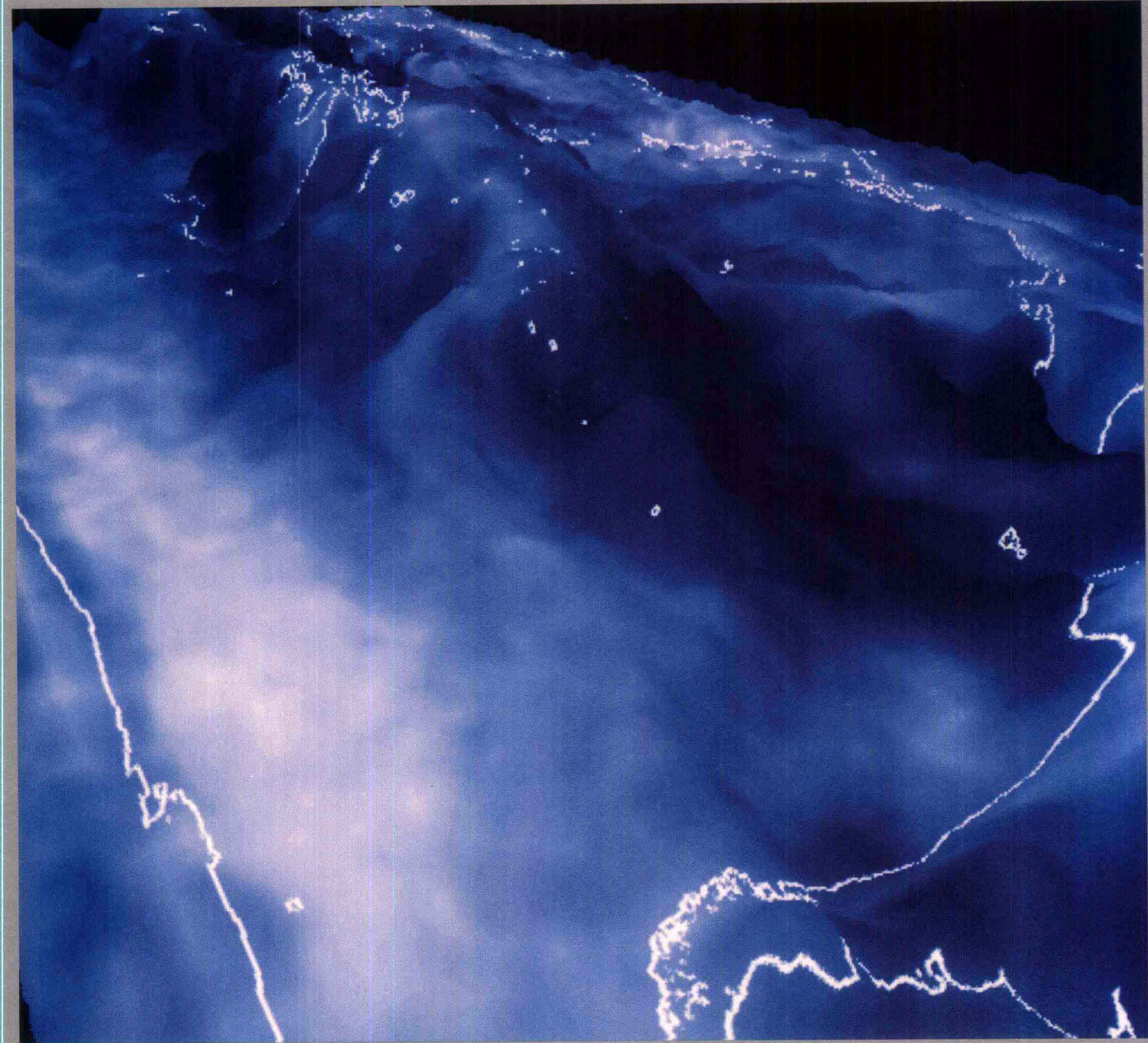
Creating three-dimensional views of cloud patterns is much easier said than done. Data for the images shown here, for example, was gathered by a weather satellite armed with twenty-two different sensors taking a wide range of measurements of the atmosphere. Complex algorithms containing as many as one and a half million lines of computer coding derived both the height and the thickness of clouds from these measurements.

Daily readings over the course of a month were then compiled and the results displayed as a three-dimensional model of the global cloud cover that could be viewed from all sorts of angles, revealing in sharp detail how clouds tend to dissipate over landmasses such as Australia and build up where trade winds converge.

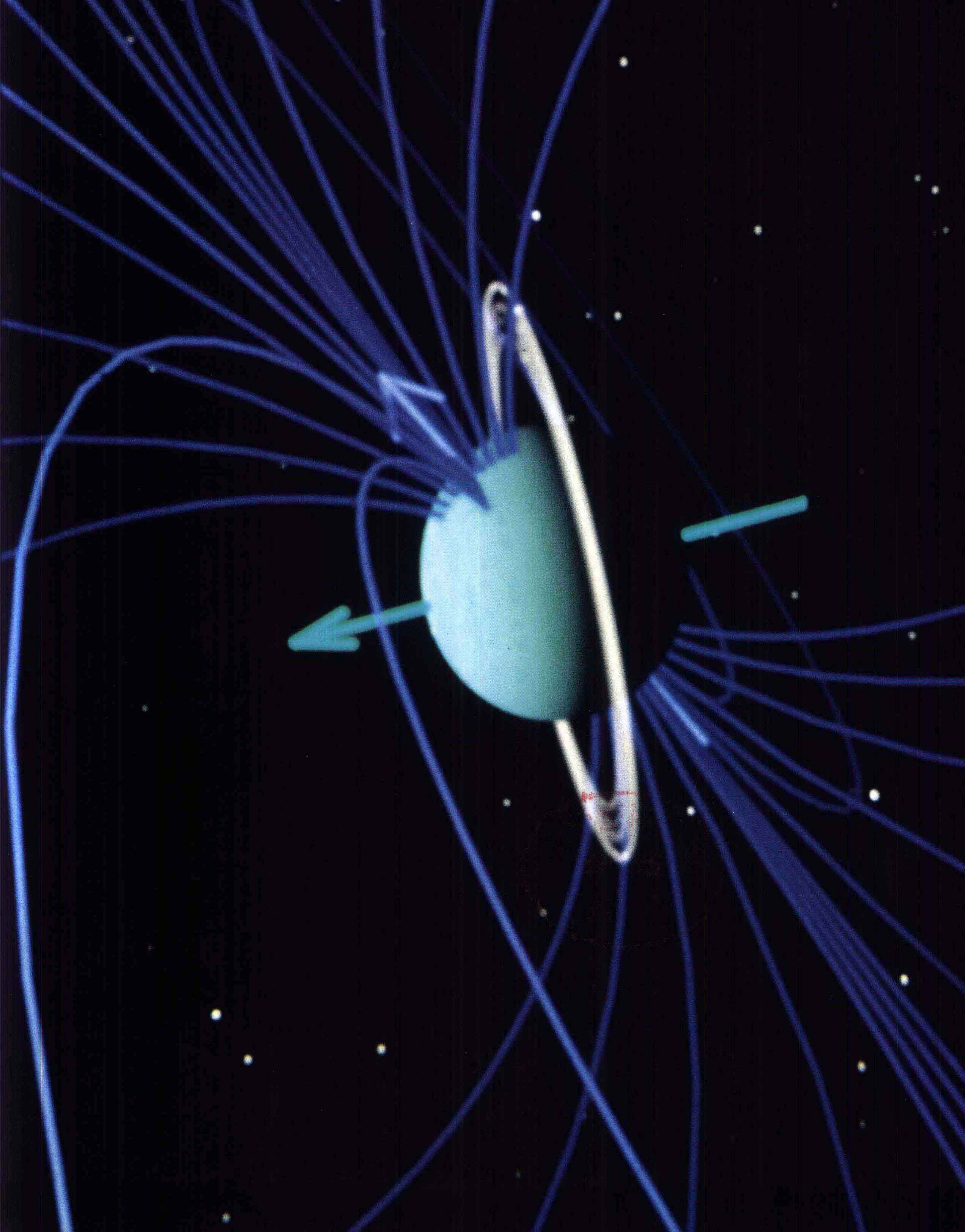




Australian flyby. The computer-generated images above and opposite illustrate the topography of the cloud cover over Australia and the southern Pacific for the month of January 1979. Cloud opacity is denoted by color, with white representing the thickest clouds and blue representing little or no cloud cover. The three-dimensional model can be manipulated to change the perspective, as if the observer were actually flying over the simulated cloud landscape. As the point of view moves from west to east in the two images above, variations in cloud height—from low, thick clouds near Antarctica *(right, bottom)* to ridges of high cloud farther north—become more apparent.



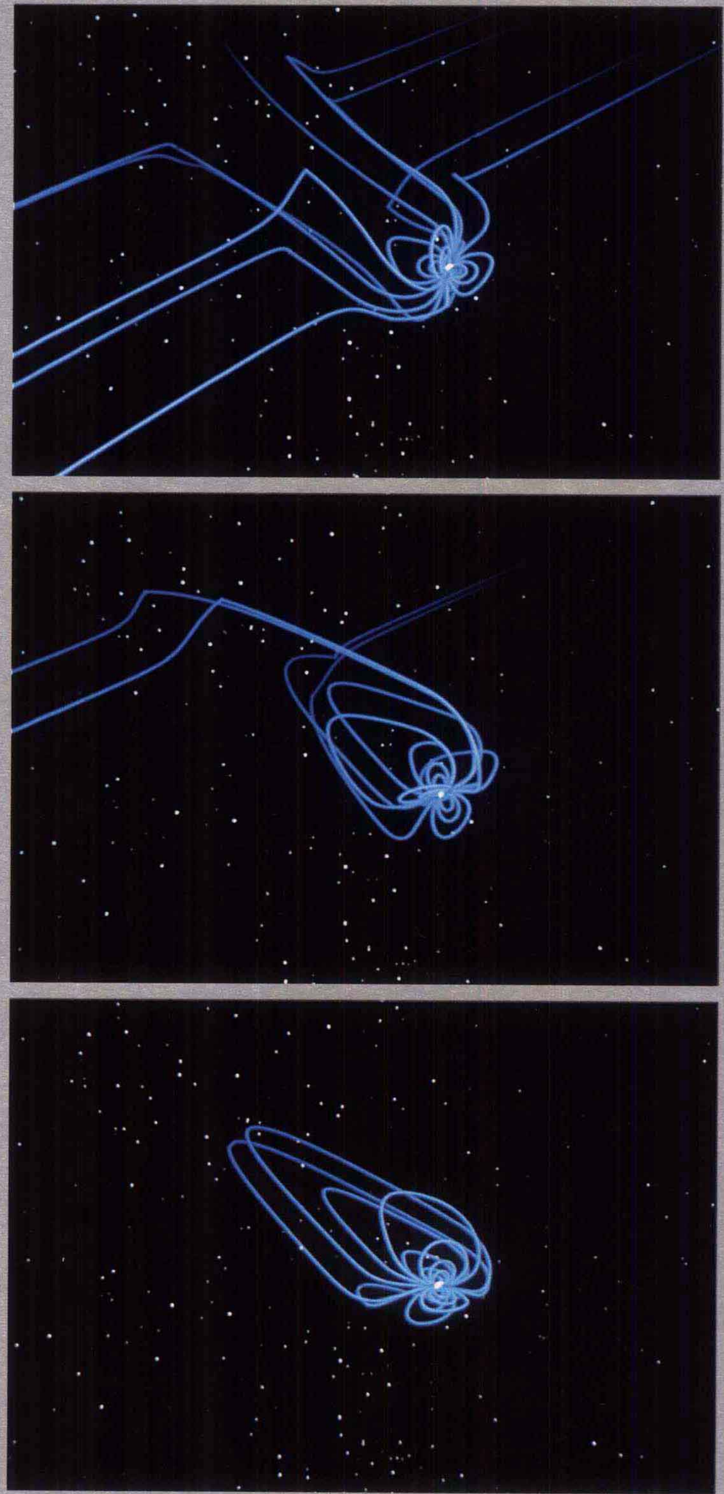
A mountainous ribbon of clouds. A view of the same cloud topography from far to the east emphasizes the long ridge of high clouds stretching from Australia *(top)* to South America *(bottom)*. This band represents an important global weather system where trade winds converge, forcing up moist air and thus giving rise to heavy rainfall in the tropics during the Southern Hemisphere's spring and summer.



Magnetic Mysteries of a Distant Planet

When the deep-space probe *Voyager 2* first encountered Uranus in January 1986, its instruments discovered a surprising phenomenon: The axis of the planet's dipolar magnetic field, unlike those of other planets such as Earth, was tilted from its axis of rotation by about sixty degrees. Typically, as a planet rotates, electrically conducting material in its liquid core induces a magnetic field whose axis tends to align with the rotational axis, sending lines of magnetic force far out into space to form a so-called magnetosphere around the planet. Uranus was already noteworthy for the unusual characteristic of lying on its side as it circles the Sun; *Voyager's* findings about the orientation of Uranus's magnetosphere were a further puzzle.

Although scientists are hard-pressed to explain the causes of Uranus's strange magnetic dynamics, computer visualization of *Voyager's* data has at least provided a clear picture of what those dynamics are. Magnetometers aboard the satellite took thousands of measurements of magnetic forces near Uranus, detecting the interactions of the Uranian magnetic field with that of the Sun. Transmitted nearly two billion miles back to Earth, the data was used to derive a complex mathematical model of the planet's magnetosphere, and computer graphics depicted the results. By studying how the lines of magnetic force in the computer animation varied over time *(right)*, scientists were able to analyze in detail the effects of the planet's oddly out-of-kilter system.



Rhythmic variation. Frames from an animated sequence show how Uranus's magnetosphere varies in shape as the planet rotates. At top, magnetic lines extend outward to connect with the Sun's magnetic field. As the Uranian magnetosphere shifts alignment after four *(middle)* and then eight *(bottom)* hours, fewer lines interact with the solar magnetic field.

◀ **A skewed magnetic field.** This computer simulation illustrates the unique orientations of Uranus and its magnetic field—the rotational axis *(aqua arrow)* pointing sunward and the magnetic axis *(purple arrow)* pitched almost perpendicular to it. Lines of magnetic force extend into space from one end of the magnetic axis and return at the other.