Physical Science

Foaming to a rough sea

Wind, water, and waves. These three ingredients combine to create a rich panoply of seascapes, from glassy ripples roused by a gentle breeze and scattered whitecaps churned up by a stiff wind to gigantic swells lashed into a drenching foam by the fury of a full-blown hurricane. Each of these responses of water to wind represents a transfer of energy and momentum from the wind to surface water waves. But the physical mechanisms by which this transfer occurs remain only partially understood.

Now Alan C. Newell and Vladimir E. Zakharov of the Arizona Center for Mathematical Sciences at the University of Arizona in Tucson have developed a simple theoretical model that focuses on what happens in rough seas whipped by high winds. In this case, the amount of energy imparted by the wind is too great for a smoothly undulating surface to absorb, and the water surface has to increase its surface area by breaking up and spraying droplets into the air. According to the researchers, this process creates a layer of foam consisting of water droplets suspended in air, and this new phase becomes the principal means by which the wind's energy is dissipated into the water.

Using their theory, the researchers calculated how foam depth and droplet size would depend on the energy flow from wind to water and on the liquid's surface tension. These predictions can be checked in the laboratory, they suggest.

At sea, a fully developed foam would probably arise only under hurricane-like conditions, the researchers say. They attribute the spottiness of whitecaps usually observed in rough seas to local energy-flow intensification associated with the passage of long, large water waves. When energy flow gets focused in a spot just ahead of a wave crest, the water surface breaks into spray. But once the wave has passed by, energy drains out of the foam left behind, and the foam disappears.

Newell and Zakharov admit that their simple theory leaves out a number of factors that may also play a role in energy dissipation and momentum transfer. During wave breaking, for example, water not only explodes into droplets but also captures air to form a cloud of air bubbles. Indeed, it's possible that a surface-hugging blanket of foam could include a top layer of water droplets in air, a middle layer of thoroughly mixed air and water, and a bottom layer of air bubbles in water. In addition, a more sophisticated model would take into consideration such factors as turbulence in the water itself.

The researchers report their results in the Aug. 24 PHYSICAL REVIEW LETTERS, describing them as "a step in the right direction" toward gaining a more complete picture of energy dissipation in wind-water interactions.

Pinpointing light for storing data

As an offshoot of earlier work aimed at perfecting an innovative, powerful optical microscope for inspecting integrated circuits, researchers at AT&T Bell Laboratories in Murray Hill, N.J., have now used essentially the same technology as the basis for storing vast amounts of digital data. Capable of packing 100 times more data into a given area than a compact disk and 300 times more bits than a conventional magnetic storage medium, this technique shows promise as a viable alternative for high-density data storage.

As described by Eric Betzig and his co-workers in the July 13 APPLIED PHYSICS LETTERS, the technique involves sending visible laser light through an aluminum-coated optical fiber tapered to a fine point only 50 nanometers wide and positioned extremely close to a special material that changes its magnetization when heated above a certain temperature. After the recording is done, a weaker laser beam sent through the same optical fiber allows one to image and "read" the resulting magnetized spots.

Space Science

A hint of fresh volcanism on Venus

What are the odds that a probe that parachuted onto Venus would encounter an active volcano during its one-day descent through the planet's dense atmosphere? Pretty slim, asserts planetary scientist Thomas M. Donahue at the University of Michigan in Ann Arbor. Nonetheless, his new analysis of chemical data from a Pioneer-Venus instrument that landed on the planet nearly 14 years ago suggests the probe did indeed pass through the plume of an active volcano.

Donahue and his collaborators, including R. Richard Hodges Jr. of the University of Texas at Dallas, characterize the findings as so surprising that they were loath to publicize them. They say the new work may provide some of the first evidence that Venus has undergone very recent volcanism. While several studies of the planet, notably the Magellan spacecraft's ongoing radar mapping mission, indicate that Venus has experienced plenty of volcanic activity in the past, no one has yet found compelling evidence of fresh eruptions.

The researchers base their unlikely conclusion on the abundance and composition of methane detected by a mass spectrometer aboard the Pioneer-Venus probe. Scientists had known for years that the spectrometer had recorded a sharp rise in methane, beginning at about 14 kilometers above the surface of Venus, during the probe's descent. But for nearly a decade, Donahue and his co-workers believed the surge merely reflected methane placed in the spectrometer on Earth in order to calibrate the instrument, not activity on Venus.

But they couldn't explain an unexpected decline in water vapor recorded by the spectrometer at about the same altitude, so the researchers took another look at the data. They discovered that the methane measured by the probe contained very little deuterium, an isotope of hydrogen that has twice hydrogen's mass but is chemically identical. In particular, the deuterium concentration in the methane was less than 10 percent of that found in the surrounding Venusian atmosphere.

The amount of deuterium relative to hydrogen in the atmosphere of a planet increases substantially over time, since hydrogen atoms weigh less and can more easily escape a planet's gravity. And in just days, fresh methane on Venus should exchange some of its hydrogen atoms for the relatively plentiful supply of deuterium in the surrounding atmosphere, so that it, too, becomes enriched in deuterium.

Thus, the deuterium-poor methane found by the probe indicated to Donahue's team that the methane must have erupted very recently from a pristine source within the planet — no more than 20 days before the instrument landed.

"We concluded that the methane sampled was a primeval methane freshly vented from the planet's interior," says Donahue. He presented the findings last month in Pasadena, Calif., at an international colloquium on Venus.

Donahue estimates that a volcanic eruption spewing out the amount of methane found by the Pioneer-Venus probe would occur only about once every 100 million years. Moreover, it appears that the probe passed through the plume near the top of the atmosphere, where winds would have stretched the vented methane over a wide area, as well as closer to the surface of the planet, where the plume would have been far more localized and less likely to have been detected.

"It is embarrassing to invoke such a wildly unlikely event as a chance encounter between the entry probe and a rare and geographically confined methane plume, but so far we have eliminated all other plausible explanations," Donahue adds.

The probe's landing site — and the location of the proposed plume — lies in a flat area about 4° north of Venus' equator, on the edge of a highland region called Phoebe Regio. Donahue's team now plans to analyze Magellan images of the area for further hints of volcanic activity.