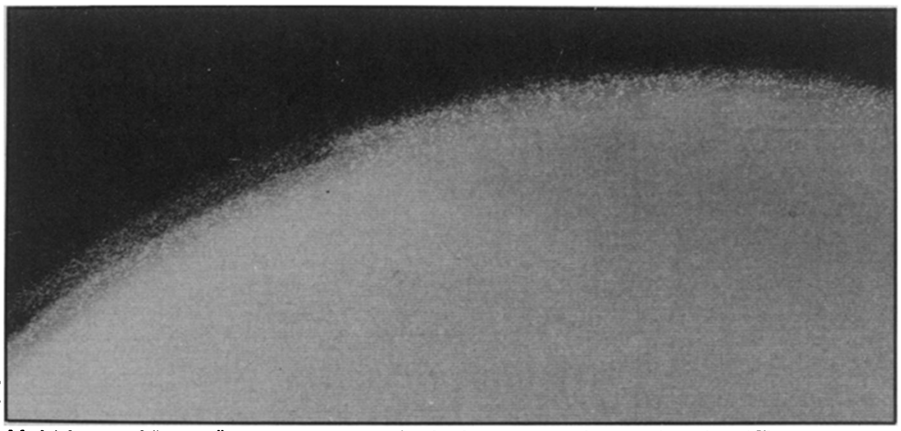
Titan: Decoding the atmosphere


Voyager 1/JPL

Multi-layered "smog" merges to a single thick cap over the north pole of Titan.

Hidden from the Voyager 1 spacecraft's cameras by clouds and photochemical smog, is Saturn's big moon Titan a murky swamp? "If so," says Von R. Eshelman of Stanford University, "it's a rather bizarre murky swamp." Methane oceans, ammonia icebergs, thick accumulations of organic goo, liquid nitrogen rain that never reaches the ground — all were among the possibilities being considered last week by a group of scientists who met at the National Aeronautics and Space Administration's Ames Research Center in California to begin the detailed study of Titan's atmosphere, hot on the heels of Voyager 1's mid-November flyby.

It was really the most preliminary of meetings, according to Jeff Cuzzi of Ames, who organized the gathering "basically just to take a good look at what we have." What they have, though much is still unanalyzed, is the first direct, closeup measurements of what has long tantalized researchers as the only satellite known to have a substantial atmosphere. Earth-based measurements had shown that much, but little else beyond the presence of methane, with traces of acetylene and ethane. The mysteries were far greater. As little as two weeks before the flyby, for example, says Stanford's Len Tyler, a poll of some of the Voyager scientists produced predictions of the atmosphere's surface pressure ranging from less than 17 millibars to 3,300 — from far less to far more, in other words, than the 1,000 mb on earth.

A trajectory that briefly had the spacecraft's earthbound radio signals passing *through* the Titanian atmosphere has now revealed a pressure of at least 1,500 mb, with no sign of the surface itself. There is more to the radio "occultation profile," and its lower portion, still being analyzed, should be capable of showing pressures as great as 3,000 mb before the signal is totally absorbed. If the surface is deeper in the atmosphere than that, the researchers will be frustrated at not finding it (they will also miss out on the surface temperature and even on Titan's exact size), but the thick "air" will give them plenty to study.

Most of the atmosphere is nitrogen, undetectable from earth but proposed by some scientists as resulting from photodissociation of ammonia (NH_3). A key question now is the amount of methane (CH_4) mixed with it, in part because its carbon is presumed to be fundamental in the formation of a variety of organic substances that may have been forming in the upper atmosphere and falling to pile up on the surface throughout most of Titan's history. Voyager 1 detected the presence of hydrogen cyanide (HCN), for example, expected as the basic intermediate building block between simple carbon-hydrogen molecules and a possible family of more complex hydrocarbons.

Careful study of the new data should yield a fairly accurate measurement, but the scientists at last week's meeting were already trying to get an idea. Earth-based infrared and visible-light observations of Titan's brightness by Kathy Rages of Ames have indicated the presence of 2 "kilometer-amagats" of methane, an amount equivalent to a column of methane 2 km high if the whole column were at 0°C and 1 atmosphere of pressure (which of course it is not). To convert that to an actual percentage of methane, however, it is necessary to know how thick a layer of atmosphere was really contributing to the observed brightness. If Rages was "seeing" down to the 1,500 mb pressure level at the bottom of Voyager 1's initial radio profile, says the University of Arizona's Martin G. Tomasko, the methane would have been mixed with about 100 km-amagats of nitrogen, indicating an atmosphere with about 2 percent methane. If the atmosphere is clear and deep enough to have been reflecting through a layer reaching down to 3,000 mb, there would only be 1 percent of methane—still plenty, Tomasko and others note, to yield material for plenty of organic chemistry on Titan.

But Voyager 1's radio data also took the atmosphere's vertical temperature profile, indicating that, at a level where the pressure was only a few hundred millibars, it may be cold enough for methane or even nitrogen to condense, forming a cloudy layer of droplets that could have represented the "bottom" of Rages's observations. If the bottom is at 600 mb, for example, says Tomasko, the observed methane would represent 5 percent of the atmosphere down to that level—and there could well be a greater amount closer to the surface.

Some of the organic materials produced after photodissociation of the methane at the top of the atmosphere were apparently seen even before Voyager 1. Polarization data from Pioneer 11, says Tomasko, indicate tiny particles of about 0.09 micron radius, and earth-based observations by Rages and James Pollack (also of Ames) indicate particles of several tenths of a micron. Owen B. Toon of Ames proposes that numerous small particles form at high altitudes and gradually combine into larger sizes that descend to the surface as they grow.

But the matter is far from resolved. Tomasko's polarization data, for example, indicate particles smaller than should have been present according to Toon's idea. Perhaps, Toon suggests, some process limits the rate at which the smallest particles can clump together, so that a greater-than-expected number of them accumulate at the high altitudes. One possibility, he says, is that they develop mutually repelling electric charges, such as from incoming cosmic rays.

Electrified or not, the small particles are clearly present, as evidenced by Voyager 1's photos and ultraviolet measurements of the "smog" they create. Furthermore, the smog seems divided into several distinct layers, which, notes Toon, could well be due to the fact that extremely small particles fall very slowly, with most of their motion taking place horizontally in response to poleward circulation of the atmosphere. The layers, in fact, apparently merge over at least the north pole into a continuous, thick blanket, suggesting that such circulation is indeed involved.

Curiously, there seems to be no such smog-cap over the south pole. At last week's meeting, one suggestion was that the difference might be related to some sort of interaction between Titan and Saturn's magnetic field. Or, the effect could be a seasonal one—and with l-o-n-g seasons. Saturn — and with it Titan — takes nearly 30 earth-years to circle the sun.

Yet all these phenomena — stratified hazes, electrically charged particles, asymmetrical polar "caps"—belong to the upper atmosphere. What's it like down below? A tantalizing hint comes from the bottommost 50 km or so of that profile measurement, which shows the atmosphere to be getting warmer with decreasing altitude. If it is warm enough at the bottom—and scientists fervently hope the remainder of the profile extends down that far — then the methane oceans and other speculative exotica may join the picture of the real Titan. □