The Weather of Venus: Also a Relation to Earth?

The raging 360-kilometer-per-hour winds that encircle Venus bear little resemblance to the swirling highs and lows, jet streams, and fronts that constitute Earth's weather. The stark contrast in appearances may belie an underlying relation between the two circulation systems. At the International Conference on the Venus Environment last November,* Gareth Williams and Leith Holloway of the Geophysical Fluid Dynamics Laboratory in Princeton, New Jersey, suggested that the general pattern of atmospheric circulation on Venus is merely a variation on Earth's global circulation. In fact, they derive circulation patterns for all the planets, including Mars, Jupiter, and Saturn, from Earth's by taking account of a few simple differences between the planets.

The crucial differences, they say, are in the rates of rotation. If Earth could be slowed from its 24-hour rotation period to Venus's 117-day rotation, Earth's highs and lows (its centers of fair weather and foul) would fade away they say. Its mid-latitude jet streams would narrow, drift toward the poles, and disappear. The closed circulation loops, or Hadley cells, driven by rising warm air at the equator would push from low latitudes all the way to the poles. In place of Earth's weather, a globe-encircling wind would blow at high altitudes.

Lacking the power to slow Earth, Williams and Holloway slowed its rotation in a computer model of its general circulation. Slowing Earth's rotation has two important effects, they say. One is a drastic reduction of the Coriolis effect, which is responsible for the swirling motion of terrestrial highs and lows. This sharply reduces or eliminates the influence of familiar terrestrial circulation patterns. The other effect is to emphasize the influence of the alternate heating and cooling that a rotating body experiences. Modelers usually ignore the day-night cycle in Earth models because it is too rapid to affect more than the bottommost kilometer of the weather. But on Venus the sun shines steadily on one spot for 50 Earth days before setting.

When Williams and Holloway put this strong diurnal effect into a circulation model whose winds had already been weakened by the reduction in the Coriolis effect, Venus-like winds sprang up. "The trend is in the direction of Venus," says Conway Leovy of the University of Washington. "It's an excellent approach and they're on the right track, but it's not complete yet." Their model is still rather Earth-like, he says. The atmosphere of the model is much shallower and thinner than Venus's and the sun's energy is not deposited mainly within a high cloud layer, as it is on Venus.

Leovy and others note that, even if the model does not yet reproduce Venus's circulation exactly, it does show that a driving mechanism for the winds, proposed in 1975 by Peter Gierasch of Cornell University, could work on Venus. Gierasch suggested that a mean circulation, such as the equator-to-pole Hadley cells, could drive the winds if it interacted with a horizontal mixing process. The diurnal effect would seem to provide the required horizontal mixing. Other theorists, including Williams, caution that the model's success does not prove that the atmosphere of Venus functions in the same way. Other explanations are still in the running.

Although there are alternatives for Venus, no other approach to understanding planetary circulations has been applied to so many planets. In the case of Jupiter, the rotation period is shortened to 10 hours, greatly augmenting the Coriolis effect. The result is alternating bands of strong winds much like those seen on Jupiter (*Science*, 12 September 1980, p. 1219). This surprises many researchers because Earth and the gas giants are so different.

Williams contends that there is nothing mysterious about finding some Jovian features in a modified Earth model. The higher rotation rate can account for the extreme stability of the circulation patterns, he says, because it shrinks the disruptive eddies and smooths the feeding of energy into the general circulation. The ranging of wind bands into higher latitudes on Saturn than on Jupiter may result from possible differences in the effective depths of their atmospheres, he says. Some features, such as the equatorial jets, do require invoking specific conditions beneath the impenetrable cloud tops that have not been verified, Williams concedes. Even so, modifying an Earth model is a powerful research tool, he says, because it puts hypothetical extrapolations from terrestrial meteorology to quantitative tests. And he needs only a computer, not a spacecraft.

*Held 1 to 6 November 1981 in Palo Alto, California. Abstracts are available from Lawrence Colin, NASA/Ames Research Center, Mountain View, California 94035.

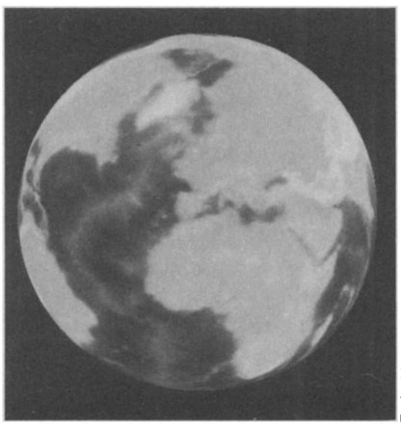
Tectonics on Venus: Like That of Ancient Earth?

Venus as the twin of Earth had been a popular theme for decades before spacecraft entered its fiery, noxious atmosphere. After the arrival of the Pioneer Venus orbiter, even the surface features of Venus seemed otherworldly (*Science*, 18 January 1980, p. 289). Now, some geologists and geophysicists are suggesting that, instead of playing the role of a twin, Venus may be acting like a younger sibling of Earth.

These researchers see a family resemblance in Venus's apparent centers of recent volcanic activity. This style of geologic activity, in which at any one time Venus releases its internal heat through a few hot spots, stands in contrast to the plate tectonics of Earth. Here, much of the released heat reaches the surface in molten rock that oozes from 60,000 kilometers of volcanically active mid-ocean ridge. If Venus does indeed have hot spots but no plate tectonics, it may resemble Earth in its hotter infancy.

The evidence for recent, localized volcanic activity on Venus comes from several sources. Radar observations, first Earth-based and then from the Pioneer Venus orbiter, have revealed surface features that at least look like volcanoes. A peak in the elevated region called Beta Regio, for example, is 4 kilometers high and is capped with a depression resembling the calderas of terrestrial volcanoes. The radar brightness of the Beta region also suggests that fresh, rough lava flows cover the area. The eastern end of the Aphrodite Terra highlands has a similar appearance.

At the Venus meeting, Frederick Scarf of TRW, Inc., in Redondo Beach, California, reported that some of these surface features that look like volcanoes may be acting like volcanoes as well. Scarf has been analyzing the orbiter's observations of "whistlers," very-low-frequency radio waves supposedly produced by the lightning of the Venusian equivalent of thunderstorms. Surprisingly, "almost all of our signals come from two regions," he says. One is the vicinity of Beta, and the other is the eastern end of Aphrodite. Scarf suggests that the



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Earth at Pioneer Venus resolution

lightning clustered over geologically young volcanic areas may be arcing across clouds of volcanic dust, as happened over Mount St. Helens.

Although the clustering of lightning flashes is intriguing, it is the added coincidence of large anomalies in Venus's gravity field with young volcanic features that has impressed most researchers. As Roger Phillips of the Lunar and Planetary Institute in Houston pointed out at the meeting, the positive gravity anomaly created by a terrestrial mountain's mass is usually nullified by the negative anomaly of the root of lighter rock on which it floats. Thus, large mountains on Earth do not have large, broad anomalies. But on Venus, the largest anomaly coincides with Beta and another large one coincides with the eastern end of Aphrodite.

The most plausible way to support such highlands on Venus and still produce the observed gravity anomalies, Phillips says, is to buoy them up with slowly rising plumes of mantle-rock. Plumes are thought by some to feed magma to the active volcanoes of such terrestrial hot spots as the islands of Hawaii and Iceland. Phillips and his colleague Michael Malin of Arizona State University suggest that on Venus hot spots would pour magma onto the surface until the lithosphere (the rigid surface rock) could no longer support the added weight and it all founders back into the mantle. No plates would form and only a random sort of subduction would occur. Some scientists believe that such a process operated on Earth 3 billion years ago before Earth's heat production decreased enough to allow plate tectonics.

Although dynamically supported hot spots appear to be likely on Venus, not everyone agrees that the possibility of Venusian plate tectonics should be excluded. James Head of Brown University and Sean Solomon of the Massachusetts Institute of Technology argue that, given the limited resolution of the Pioneer Venus radar, even an exact replica of Earth's plate tectonics would be difficult to decipher on Venus. The high Venusian surface temperature and extreme dryness could only make the process more obscure, they say, perhaps creating a different and quite uninterpretable style of plate tectonics. Other researchers who have done studies similar to that of Head and Solomon have concluded that Earth's style of plate tectonics could be readily perceived on Venus. But no one has been very specific about how different Venus's version might be.

Origins: A Problem with Rare Gases

The chemical analyses made by Pioneer Venus have placed theoreticians concerned with the origin of the solar system in a quandary, and only Soviet planetary scientists have a chance to get them out of it.

The quandary arises because, during its suicidal plunge through the atmosphere, Pioneer Venus's mass spectrometer detected only about 50 parts per billion of krypton gas, but the Soviet spacecraft Venera 11 and Venera 12 have found between 700 and 1400 parts per billion of krypton. Unfortunately, plans do not exist for a repeat of the U.S. experiment.

Theorists have been using the relative proportions of the rare gases, such as krypton, neon, argon, and xenon, as clues to how a diffuse ball of gas and dust came to form the sun and planets. The detection by both Soviet and American instruments of at least 50 times more argon in the atmosphere of Venus than in Earth's had forced the reevaluation of previous formation theories (*Science*, 18 January 1980, p. 289).

Now, the low American krypton abundance on Venus has brought to the fore the possibility that the sun was a major source of rare gases. George Wetherill of the Carnegie Institution of Washington has considered how the solar wind of the infant sun might have added rare gases to the dust particles that eventually formed the planets. Under one set of conditions that might have prevailed during planet growth, the particles that eventually became Venus could have accumulated enough argon-36 from the solar wind to account for its observed abundance, he found. These particles would have in turn blocked most of the solar wind from reaching particles farther out, leaving Earth with much less argon. Because the sun is relatively poor in krypton, the low American krypton abundance is consistent with a solar source, Wetherill notes, whereas the high Soviet abundance is not.

No one is claiming yet that one measurement is right and the other wrong. Some observers wonder if the temporary clogging of the sample inlet of the American mass spectrometer (*Science*, 18 January, p. 290) might have caused a problem, but Thomas Donahue of the University of Michigan cannot imagine how that would have affected their measurements. To do so, the blockage would have had to change the proportions of argon and krypton in the sample, he says. Ulf von Zahn of the University of Bonn, who observed Soviet methods in their laboratory, says that fears of contamination by the krypton used to calibrate the Soviet instrument are unfounded. American mass spectrometrists remain unconvinced of that.

Venera 13 and Venera 14, now on their way to Venus, might help to resolve the problem. But even if the Soviets have the best data on krypton, neon and xenon have yet to be accommodated by theories of solar system formation. "It's going to be very complicated," Wetherill says. "There seems to be no simple explanation of the rare gases."

Richard A. Kerr