# Saturn's Moon Titan: Cassini-Huygens Reveals a New World

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The year 2005 will be remembered in the history of space exploration for the first landing of a probe on a surface in the outer solar system. On January 14, the Huygens probe landed on the surface of the mysterious moon Titan, revealing a landscape carved by channels, showing evidence that liquids have, or still flow, on the surface. Meanwhile, the Cassini orbiter spacecraft obtained many observations of Titan's surface and atmosphere using several instruments including radar, an infra-red mapping spectrometer, and a camera. This talk will discuss the results from both Cassini and Huygens, with a focus on the geology of the surface.

Titan, Saturn's largest moon, was discovered in 1655 by Dutch astronomer Christiaan Huygens. At 5,150 km in diameter, Titan is larger than the planets Mercury and Pluto. Its atmosphere is the second densest of the solid bodies in the solar system (Venus has the densest), and its surface, shrouded by a thick atmosphere, is extremely cold, about 95 K (-178$^{o}$C). Titan's thick atmosphere is about 95% nitrogen, with a few percent methane. The photochemical processes in Titan's atmosphere are thought to be similar to those in the early Earth and it is likely that understanding the atmospheric processes on Titan will contribute to knowledge of the Earth prior to the evolution of life. However, the atmosphere makes it difficult for spacecraft instruments to observe the surface. When the Voyager 1 spacecraft flew by Titan in 1981, its cameras showed an orange ball, much to the disappointment of planetary geologists. The Cassini orbiter instruments were designed to penetrate the haze and image the surface. In particular, the Titan Radar Mapper has been able to reveal the surface in unprecedented detail, using its Synthethic Aperture Radar (SAR) mode.

Cassini and Huygens have shown that Titan's surface is remarkably varied and, apparently, quite young in planetary terms. Only two impact craters have been found, far less than would be expected in comparison with other Saturn satellites. In general, the older a surface has remained unmodified, the more craters it will display. The relatively small number of impact craters on Titan indicates that craters must be destroyed by recently or currently active geologic processes. The major geologic processes shaping all planetary surfaces are volcanism, tectonism, impact cratering, and erosion. Since the scars of impacts are being erased on a large scale, one or more of the other processes must be responsible. Radar images of Titan have shown evidence of volcanism in the form of a dome and extensive flows. Ridges that may be tectonic in origin are also seen in radar images. Other radar images, as well as Huygens images, showed alluvial deposits and fields of dunes, indicating erosion by liquids and wind on a large scale. Titan appears to be a dynamic world, in some ways remarkably Earth-like in its geology.

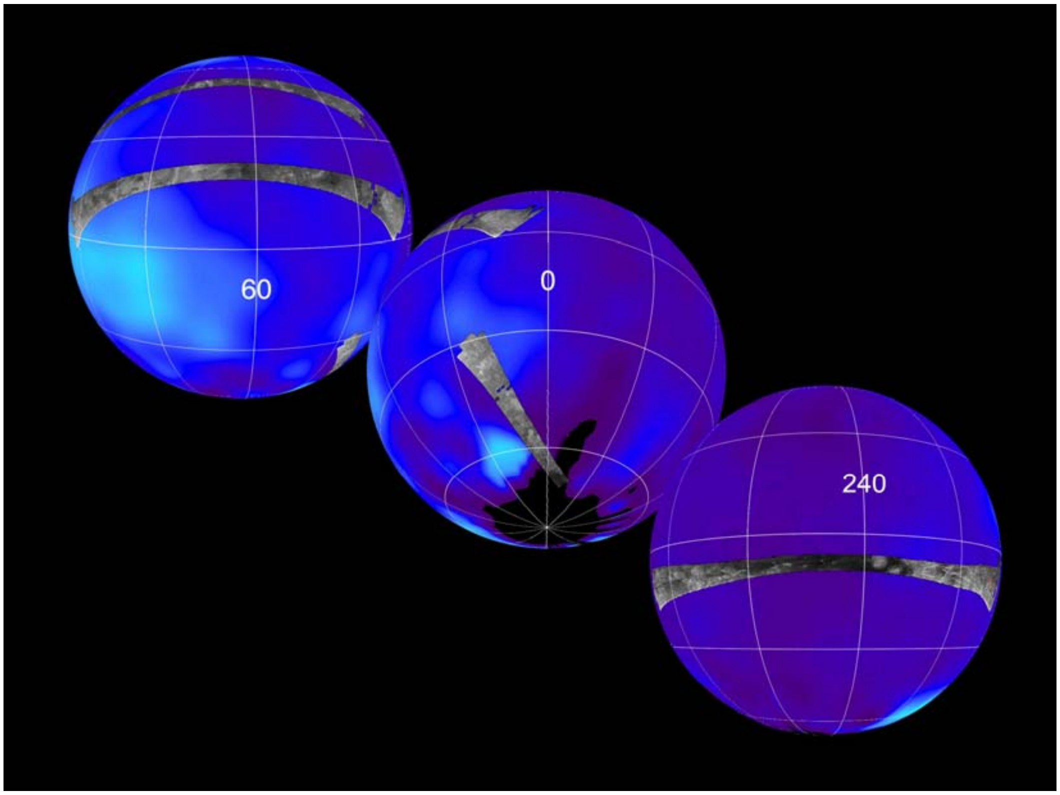
However, when looked at in detail, Titan and Earth are not at all similar. While water carves river valleys on Earth, the liquid on Titan is likely to be methane. Liquid methane may exist in lakes or pools on Titan, such as in some dark areas imaged by Cassini's camera and radar. Methane may also come down in the form of rain, and we know from

Cassini orbiter images that methane is present in clouds near the south pole. Rivers of methane may carve dendritic channels such as those seen in radar and Huygesn images. Volcanism on Titan is also nothing like Earth's. The flows and dome seen in radar images were formed by cryovolcanism, where the "magma" is not molten rock but liquid water coming from below the frozen surface, most likely mixed with other components such as ammonia.

One of the most remarkable surprises from the orbiter's radar images was the discovery of "sand seas", that is, large areas of the surface covered by dunes that appear similar to longitudinal dunes on Earth, such as those in Namibia. This is further proof that Titan's surface and atmosphere are indeed dynamic, and that weather on Titan has a great influence on the appearance of the surface.

Cassini-Huygens observations of Titan are showing us that geologic processes, even when involving materials that are very different from those we find on the Earth's surface, can shape features that are remarkably similar to terrestrial geologic features. We look forward to several more years of observations using the Cassini orbiter and many more fascinating findings.

Cassini has found Titan's upper atmosphere to consist of a surprising number of layers of haze, as shown in this ultraviolet image of Titan's night side limb, colorized to look like true color.




This set of images shows the areas mapped so far on Saturn's moon Titan by the Cassini Titan Radar Mapper using its synthetic aperture radar (SAR) imaging mode. Labels represent the approximate central longitude of each globe. The radar swaths are superimposed on a false-color image made from observations by NASA's Hubble Space Telescope. The radar swaths were from the first four fly-bys of Titan during which the SAR mode was used. These combined radar passes reveal a variety of geologic features, including impact craters, wind-blown deposits, channels and cryovolcanic features.

Large areas of this Cassini synthetic aperture radar image of Titan are covered with long, dark ridges spaced about 1 to 2 kilometers apart. They curve slightly around teardrop-shaped bright terrain, giving the impression of a Japanese garden of sand raked around boulders. The bright material appears to be high-standing rough material that the ridges bend around. This suggests that the ridges are dunes that winds have blown across the surface of Titan from left to right (roughly west to east).

Huygens view of Titan's surface obtained using the Descent Imager/Spectral Radiometer on January 14, 2005. This is a colored view, following processing to add reflection spectra data, and gives a good indication of the actual color of the surface. Several rounded pebbles are seen. The two just below the middle of the image are about 15 centimeters (left) and 4 centimeters (center) across, at a distance of about 85 centimeters from Huygens. The surface is darker than originally expected, consisting of a mixture of water and hydrocarbon ice.