Early Titan was a cold, hostile place for life

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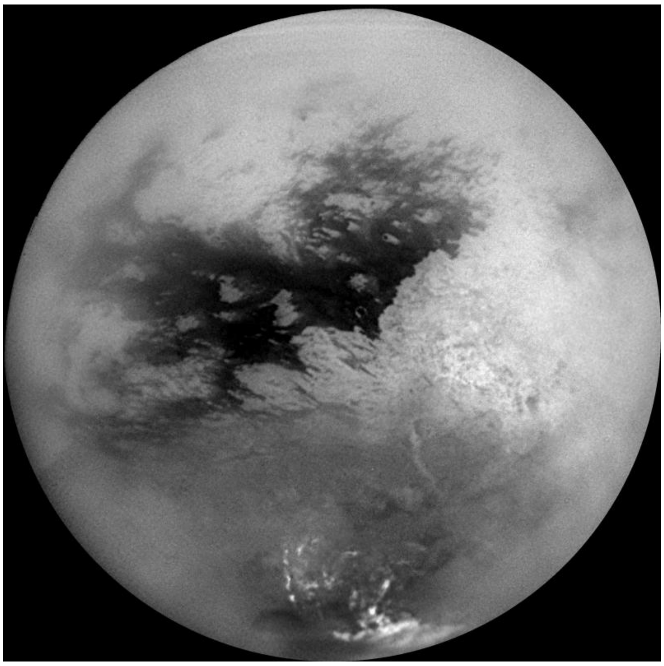


Titan's thick clouds make surface observations impossible unless researchers use techniques such as radar. Credit: NASA/JPL/Space Science Institute

Titan is a mysterious orange-socked moon of Saturn that is exciting to astrobiologists because it has some of the same kinds of chemicals that were precursors to life on Earth. It also has a hydrological cycle that allows liquid to move between the ground and atmosphere, providing a cycle that could support life.

Its atmosphere is 95 percent nitrogen, but it also has a tad bit of methane, predominantly close to the surface. The methane is important because it contributes to a slight greenhouse effect on the moon, although its average temperature is still a frigid -292° Fahrenheit. Yet without this greenhouse effect, the methane would freeze at the surface and make it difficult for any life that might be present to survive.

What produces the methane on Titan is a mystery. On Earth it comes from biological processes and volcanoes, among other sources.

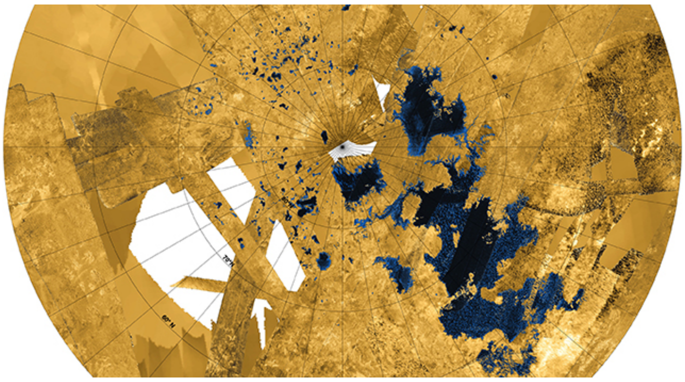
Titan's methane is thought to be less than a half billion years old, leading astrobiologists to wonder what Titan's atmosphere looked like early in its history when there was little to no methane present. Could it reflect what Earth might have looked like earlier in our planet's history before life arrived?

Most likely early Titan was a world surrounded by an almost pure and clear nitrogen atmosphere, with a similar surface pressure to today but with a lesser greenhouse effect, said Benjamin Charnay, a planetary scientist who was at the Laboratory of Dynamic Meteorology at the P&M Curie University in France when the research was conducted.

"Looking at Titan's past helps us to understand where the methane comes from and how the photochemistry evolved," said Charnay. now a post-doctoral researcher at the University of Washington. "The photochemistry in Titan's past with less atmospheric methane may have been closer to the atmospheric chemistry on the early Earth that could have led to the emergence of life."

Charnay added that if methane was present in Titan around four billion years ago, today there would be large seas of ethane rather than the smaller polar lakes we observe. His research was recently published in the journal Icarus under the title, "Titan's past and future: 3D modeling of a pure nitrogen atmosphere and geological implications."

Valley networks



Northern lakes and seas on Titan, which are full of methane but are likely hostile to life, one research team says. Credit: NASA/JPL-Caltech/ASI/USGS

Charnay and his collaborators used a model to simulate the global climate of Titan early in its history, assuming that the moon was almost completely a nitrogen environment. The model, called Generic LMDZ, is fairly new but has been used in several other studies to simulate Earth's early climate and climates of planets outside of our solar system.

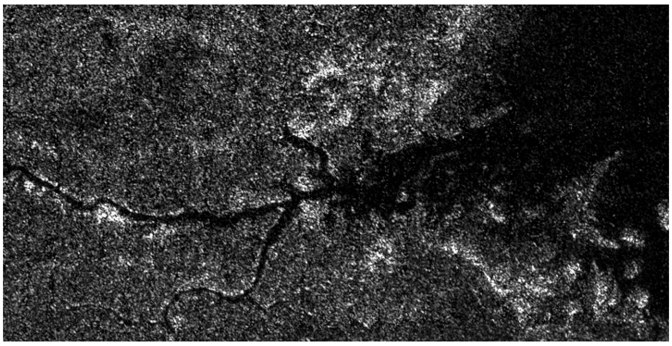
They discovered that without methane, the greenhouse effect on Titan largely disappears, leading to dramatic climate changes in the moon. In the model, the atmosphere cooled and condensed, producing nitrogen clouds and polar seas of liquid nitrogen. At the poles, the nitrogen atmosphere froze.

With a very high surface reflectivity, liquid nitrogen would have to freeze at the surface, as on Neptune's moon Triton. But such a high reflectivity in Titan's past remains unlikely. Charnay's group suspects the nitrogen was liquid, as it could explain some of the valley networks we see today on Titan's surface.

"Liquid nitrogen could erode the surface much more efficiently than liquid methane, producing valley networks and removing the impact craters which are used to estimate the age of the surface," Charnay said. "On Titan, we currently see valley networks, but we don't know exactly how they formed."

He continued:

"Titan's climate is quite dry today, with little methane precipitation. The formation of valley networks is challenging for such conditions. Researchers believe that Titan was wetter in the past, with more methane rain explaining the formation of valley networks. It is a reasonable scenario. But we believe that liquid nitrogen could also have played a significant role."



A valley network on Titan of unknown origin. One new climate model suggests nitrogen could have created it. Credit: NASA/JPL-Caltech/ASI

Liquid nitrogen could also explain why the poles of Titan are flattened compared to the rest of the planet. Over time, the nitrogen would have seeped into the crust and remained there, increasing its density and making the poles flatter.

Life lurking underground?

Charnay's research aimed to better understand how Titan appeared early in its history, and did not consider the question of life. However, looking at how a planetary atmosphere forms and evolves can give clues about the likelihood of microbes or other lifeforms surviving over time.

On Titan, the major barrier to life in its early history would have been a lack of liquid water at the surface, which means it would have been difficult for microbes to exist in Titan's methane lakes with the chemistry we understand from Earth. Researchers today believe the best bet for life would be an internal ocean, which was recently detected by the Cassini mission. It is believed the ocean contains methane and water.

"This could also be true of the oceans of the moons of Ganymede and Europa at Jupiter, and maybe Enceladus at Saturn as well," Charnay said.

In the future, Charnay and his collaborators hope to better explain the atmospheric evolution of Titan over time. In the long term, the methane will likely be destroyed by chemical reactions in the atmosphere, so it's possible that Titan could once again become a colder, nitrogen-dominated world.

More information: "Titan's past and future: 3D modeling of a pure nitrogen atmosphere and geological implications," *Icarus*, Volume 241, October 2014, Pages 269-279, ISSN 0019-1035, dx.doi.org/10.1016/j.icarus.2014.07.009

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