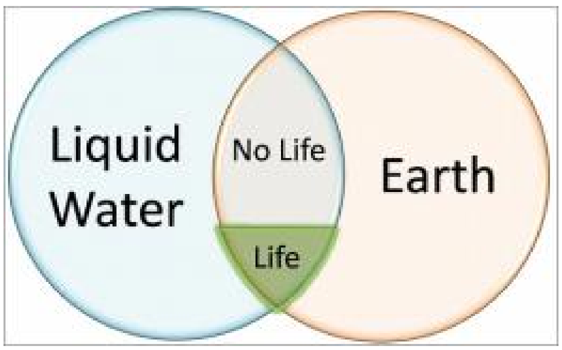
# Water, Water Everywhere, but Not All Drops Have Life

May 21 2010, by Michael Schirber




Only about 3.5 percent of the Earth's volume has the right temperature and pressure for liquid water. And of this region, only 12 percent of it contains life. Image Credit: Jones & Lineweaver/Australian National University

The search for life on other planets focuses on water, but researchers argue that - judging from our own planet - a large fraction of water conditions may be inhospitable to life.

Water is vital for life as we know it. But not all water has life living in it. By combing through data from extreme environments, researchers have found the limits of what constitutes habitable water conditions on our planet. This could help us figure out what types of water on other planets would be more likely to host life.

The guiding principle in our current search for alien biology is "follow the water." But the new research suggests this target needs to be refined.

"Should we follow the hot water or maybe the cold water?" asks Eriita Jones of the Australian National University, lead author of the study that appears in the latest issue of the journal Astrobiology.

On Earth, we know that life can survive in a wide variety of water temperatures and pressures, and yet there are watery places where no living things have been found. Jones and her colleague Charles Lineweaver have performed a comprehensive survey of just how far life has expanded into the available "water territory" on Earth.

"We try to quantify our understanding of the terrestrial biosphere better," Jones says.

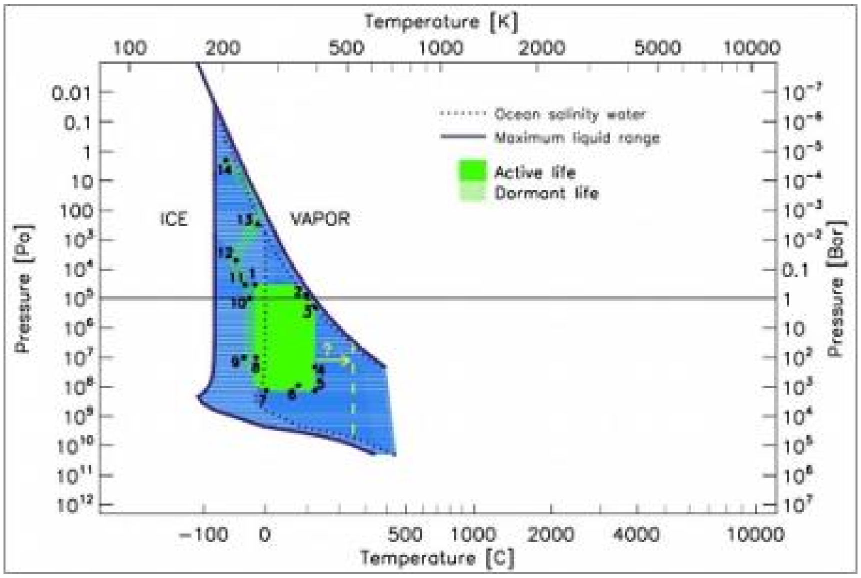
Their results show that only 12 percent of the volume of the Earth where liquid water exists is known to host life. As for the rest of this volume, life presumably never found a way to adapt to the conditions there, despite having had several billions of years of evolution to work with.

This may mean that some fraction of liquid water is strictly uninhabitable - both here and on other distant worlds.

## Water diagram

To quantify what constitutes habitable water, Jones and Lineweaver plotted the range of water conditions on a pressure and temperature diagram.

"This is a very natural way to parameterize any planet," Jones says.




The blue-shaded region indicates the range of temperature and pressure in which water is in its liquid form. The green-shaded region shows the extent that life on Earth has populated the parameter space of liquid water. Image Credit: Jones & Lineweaver/Australian National University

Although we typically think of water being liquid between zero and 100 degrees Celsius, this is only true for pure water at Earth's sea level atmospheric pressure (about 14.7 pounds per square inch or 1014 millibar). If salt is present, water's freezing point drops below zero degrees and its boiling point rises above 100 degrees.

At high pressure, as well, water remains liquid above 100 degrees Celsius. In fact, the authors estimate that liquid water can exist to a maximum depth of 75 kilometers below the Earth's surface, where the temperature is more than 400 degrees Celsius and the pressure is 30,000 times that at the surface.

But could life live in this water? Probably not. The highest temperature known to support life is 121 degrees Celsius. Some biologists believe organisms might survive at even higher temperatures, but nothing has broken the record yet.

Jones and Lineweaver take the current limit of 122 degrees Celsius to be the upper temperature boundary for habitable water. At the other end of the thermometer, liquid water can be found on Earth at 89 degrees below zero in thin films. However, the coldest water temperature known to support active life is 20 degrees below zero, which is what the researchers take as their lower habitable boundary.


Conditions on Earth do not allow liquid water below a depth of about 75 km. That leaves a thin outer shell where liquid water can exist. Out of the entire Earth volume, 3.3 percent has the right conditions for liquid water but not life, while only 0.2% has the potential for habitable water. Image Credit: Jones & Lineweaver/Australian National University

The researchers also looked at pressure limits. Life has been found as far down as 5.3 kilometers below the surface, where the pressure is 1500 times that at the surface. Whether this is truly the highest pressure for habitable water remains to be seen, since no one has yet dug deeper in search of life.

"We have so far found life as deep as we have looked," Jones says.

As for low pressure, life has been found high up in the atmosphere where the air is thin, but these microorganisms are typically dormant and are only revived when given the necessary nutrients. The authors therefore take the low pressure limit for active life to be one third of atmospheric pressure, which corresponds to the altitude at the top of Mt. Everest.

## Biosphere limits

According to the above limits, life on our planet is restricted to a thin shell that roughly extends from 10 kilometers above the surface down to 5 kilometers below (or to depths of 10 kilometers in the ocean). This leaves uninhabited 88% of the volume where water exists on Earth.

"It shows that life and water are not equivalent," Jones says. "There may be a lot of liquid water that is hostile to life."

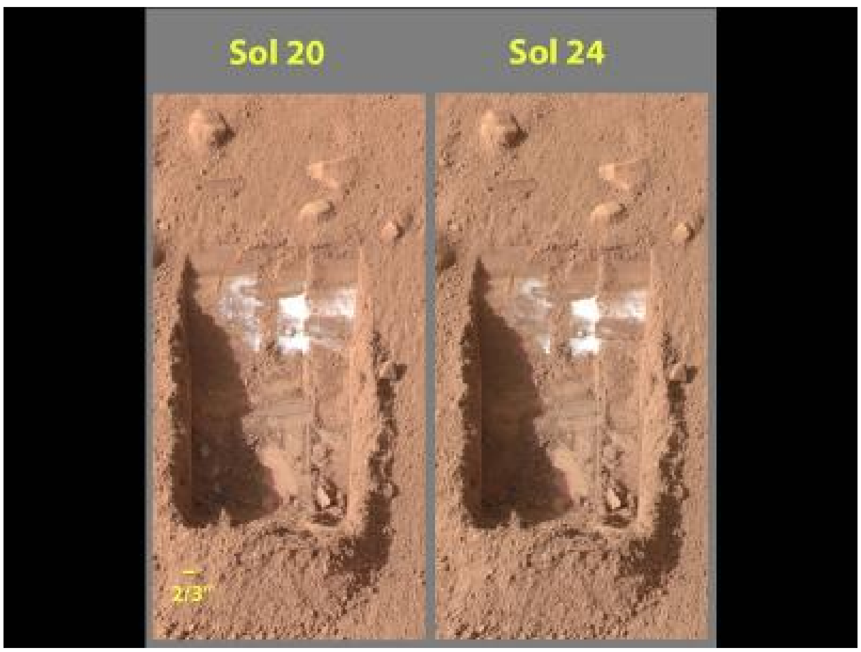
Nearly all of Earth's liquid water is located in habitable regions. The point is that only a small fraction of the water conditions on Earth are friendly to life.

"Stated this way it sounds surprising and seems to suggest that the 'follow the water' strategy for life search needs rethinking," says Chris

McKay of the NASA Ames Research Center.

But he thinks this is slightly misleading. The only truly constraining factor in this analysis is the observation that life apparently can't survive above 122 degrees Celsius.

"None of the other worlds (save Venus) have surface temperatures that are hot enough to make this limit relevant," McKay says.




NASA's Phoenix Mars Lander obtained direct evidence of water ice on the surface of Mars. Liquid water may exist farther down beneath the surface, where the temperature and pressure are higher. Image Credit: NASA/JPL-Caltech/University of Arizona/Texas A&M University

However, hotter temperatures can be found below the surface. Mars, for instance, may be too cold for liquid water on its surface, but there is reason to believe that there is liquid water underground.

Jones and Lineweaver are currently modeling the crust, mantle and core of Mars and using heat flow estimates to construct a Martian water phase diagram, like the one they made for Earth's water. The results will show at what depths potentially habitable water (as defined by the current study) might be found on Mars.

This sort of "habitable water" analysis could also be used for the liquid oceans that are thought to lie beneath the icy crusts of Jupiter’s moon Europa and Saturn’s moon Enceladus. And it may help characterize exoplanets for which a reasonable phase diagram can be estimated.

"It may show us where to focus our search for life," Jones says.

Source: Astrobio.net