PRESS RELEASE I PARIS I 11 DECEMBER 2013

NB: Embargoed until 7:00 pm 11 Dec. 2013

When will the Earth lose its oceans?

The natural increase in solar luminosity—a very slow process unrelated to current climate warming—will cause the Earth's temperatures to rise over the next few hundred million years. This will result in the complete evaporation of the oceans. Devised by a team from the Laboratoire de Météorologie Dynamique[1] (CNRS / UPMC / ENS / École polytechnique), the first three-dimensional climate model able to simulate the phenomenon predicts that liquid water will disappear on Earth in approximately one billion years, extending previous estimates by several hundred million years. Published on December 12, 2013 in the journal *Nature*, the work not only improves our understanding of the evolution of our planet but also makes it possible to determine the necessary conditions for the presence of liquid water on other Earth-like planets.

Like most stars, the Sun's luminosity very slowly increases during the course of its existence[2]. It is therefore expected that, due to higher solar radiation, the Earth's climate will become warmer over geological timescales (of the order of hundreds of millions of years), independently of human-induced climate warming, which takes place over decades. This is because the amount of water vapor in the atmosphere rises as the oceans become warmer (the water evaporates faster). However, water vapor is a greenhouse gas that contributes to the warming of the Earth's surface. Scientists therefore predict that runaway climate warming will occur on Earth, causing the oceans to boil and liquid water to disappear from the surface. Another consequence is that the greenhouse effect will enter a runaway state and become unstable, making it impossible to maintain a mild mean temperature of 15 °C on Earth. This phenomenon may explain why Venus, which is a little nearer to the Sun than the Earth, turned into a furnace in the distant past. It also sheds light on the climate of exoplanets.

When might this runaway state occur on Earth? Until now, this was difficult to estimate as the phenomenon had only been investigated using highly simplified astrophysical (one-dimensional) models, which considered the Earth to be uniform and failed to take into account key factors such as the seasons or clouds. Yet the climate models used to predict the climate over the coming decades are not suited to such high temperatures. According to some of these one-dimensional models, the Earth would start to lose all its water to space and turn into a new Venus within a mere 150 million years.

A team from the Laboratoire de Météorologie Dynamique (CNRS / UPMC / ENS / École polytechnique) has now designed a three-dimensional model able to predict how the terrestrial environment would change under the effect of a significant increase in solar flux causing evaporation of liquid water into the

[1] The Laboratoire de Météorologie Dynamique is part of the Institut Pierre-Simon Laplace (IPSL). The project was granted an Ile-de-France Region post-doctoral research allowance.

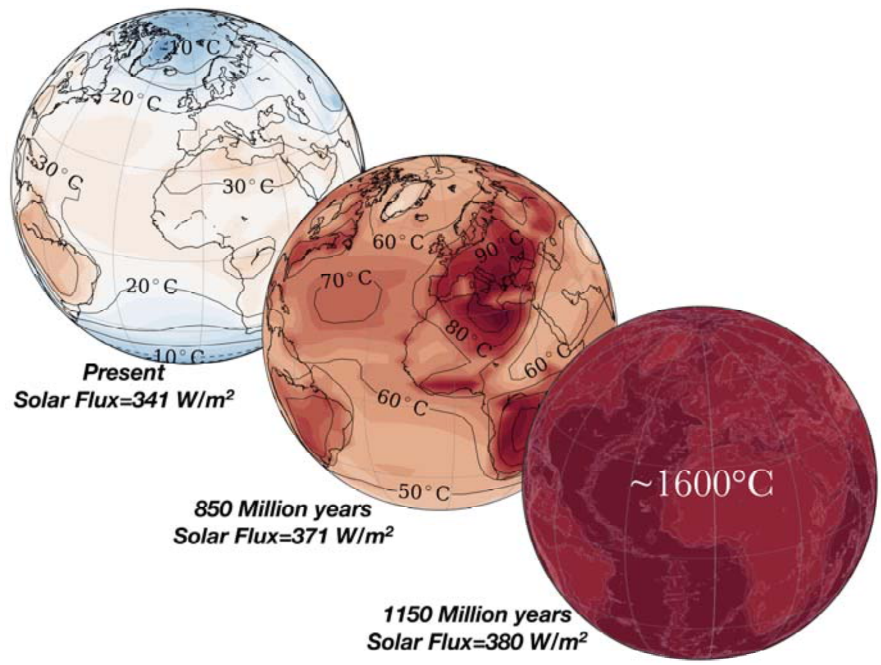
[2] It is estimated that at the origin of the Solar System 4.5 billion years ago, the Sun's luminosity was 70% of today's value, which implies an increase of around 7% every billion years.

atmosphere. According to this sophisticated model, the tipping point should occur when mean solar flux reaches approximately 375 W/m^2, with a surface temperature of around 70 °C (present-day flux is 341 W/m^2), i.e. in approximately one billion years. The oceans will then start to boil and the greenhouse effect will increase until it enters a runaway state. This result pushes back earlier predictions for the complete evaporation of the oceans by several hundred million years.

This difference is due to atmospheric circulation: while transporting heat from the equator to the mid-latitudes, it dries these warm regions and reduces the greenhouse effect in the areas where it is most likely to enter a runaway state. Increased solar flux appears to intensify this atmospheric circulation, drying sub-tropical regions even more and stabilizing the climate for several hundred million years before it reaches the point of no return. In addition, this work shows that the parasol effect of clouds, in other words their ability to reflect solar radiation—which helps to cool the present-day climate—tends to decrease over millions of years compared to their greenhouse effect. The parasol effect is therefore likely to contribute to climate warming and destabilization.

These findings can also be used to determine the extent of the habitable zone around the Sun. They show that a planet can be as close as 0.95 astronomical units[3] to a star similar to our Sun (i.e. 5% less than the distance from the Earth to the Sun) before losing all its liquid water. In addition, they demonstrate yet again that a planet does not need to be exactly like the Earth to have oceans. The researchers are now planning to apply this model to extrasolar planets in order to determine which environments could help them retain liquid water.

[3] 1 astronomical unit (AU) = 150 million kilometers.



Numerical simulations of the Earth's surface temperatures at the spring equinox, with an increasingly luminous Sun in the future. The first two diagrams are obtained with the global climate model. The second one shows the situation just before the complete evaporation of the oceans. The last one (380 W/m²) is an extrapolation showing temperatures after the complete evaporation of the oceans. The dates, expressed in Myr (millions of years), indicate the Sun's evolution: in reality, the continents and topography will be totally different in this distant future. © Jérémy Leconte

Reference

Increased insolation threshold for runaway greenhouse processes on Earth-like planets. Jérémy Leconte, François Forget, Benjamin Charnay, Robin Wordsworth, and Alizée Pottier. *Nature.* 12 December 2013. DOI: 10.1038/nature12827

Contact information

Researchers l Jérémy Leconte l T +1 647 895 2100 l jeremy.leconte@lmd.jussieu.fr
François Forget l T +33 6 71 20 07 50 l forget@lmd.jussieu.fr
CNRS Press Office l Priscilla Dacher l T +33 1 44 96 46 06 l priscilla.dacher@cnrs-dir.fr