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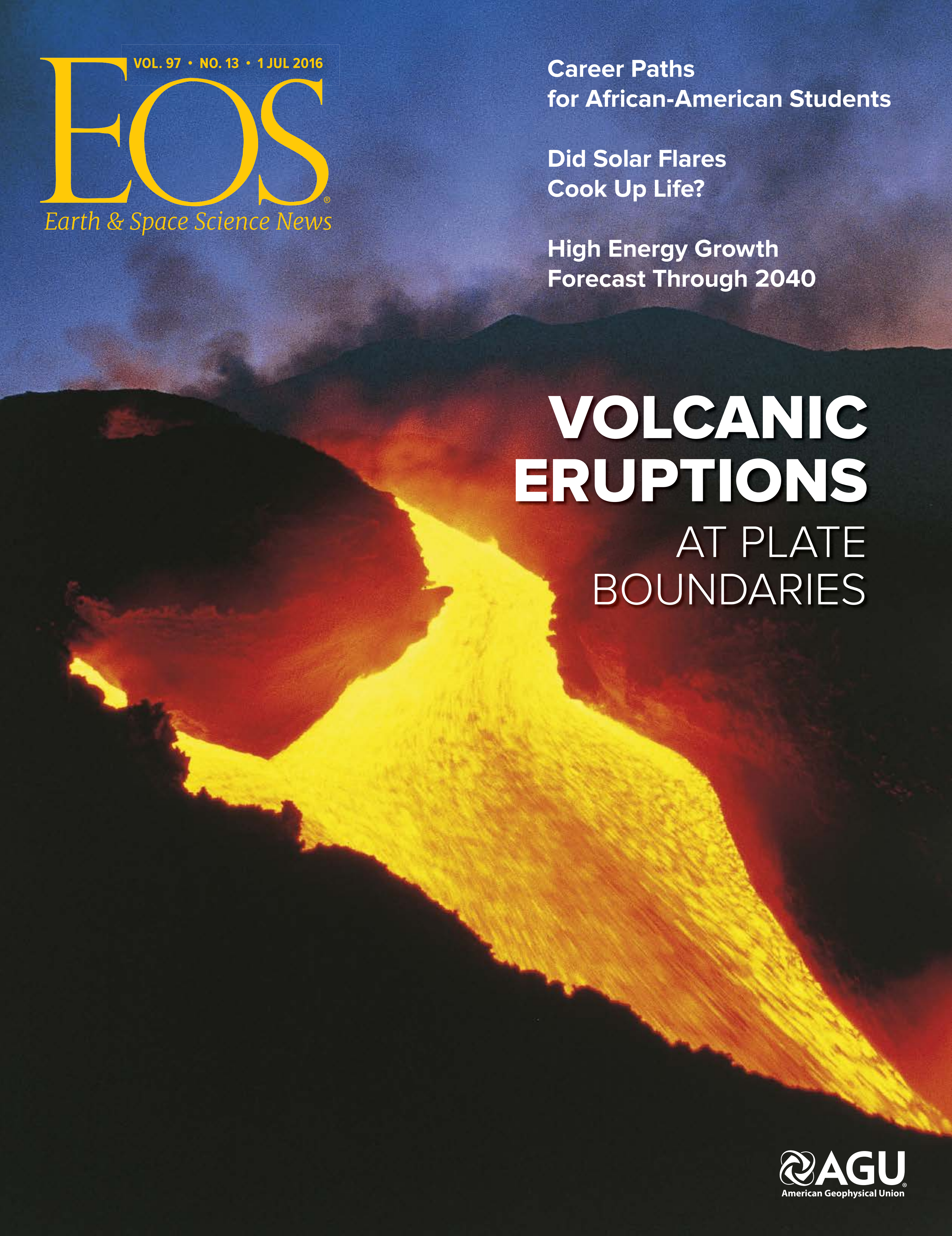

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Did Solar Flares Cook Up Life on Earth?

Space weather today threatens our satellites, our space station, and our telecommunications, but 4 billion years ago, large solar flares and their associated energetic particles could have provided the planet its first ingredients for life.

Researchers at NASA have found that when the Sun was about half a billion years old, large solar flares—larger than any recorded by humans—could have changed the very chemistry of Earth's atmosphere. What's more, bombardment of the planet by high-energy particles from those jets of superhot solar plasma might have prompted organic molecules considered precursors to life to form from simpler inorganic molecules then abundant on primordial Earth.

One of the types of molecules that could have newly formed back then is a potent greenhouse gas. Thus the findings may illuminate a long-standing mystery about how Earth could have been so warm and hospitable to life at a time when, despite the solar flares, the Sun was significantly less bright than it is today.

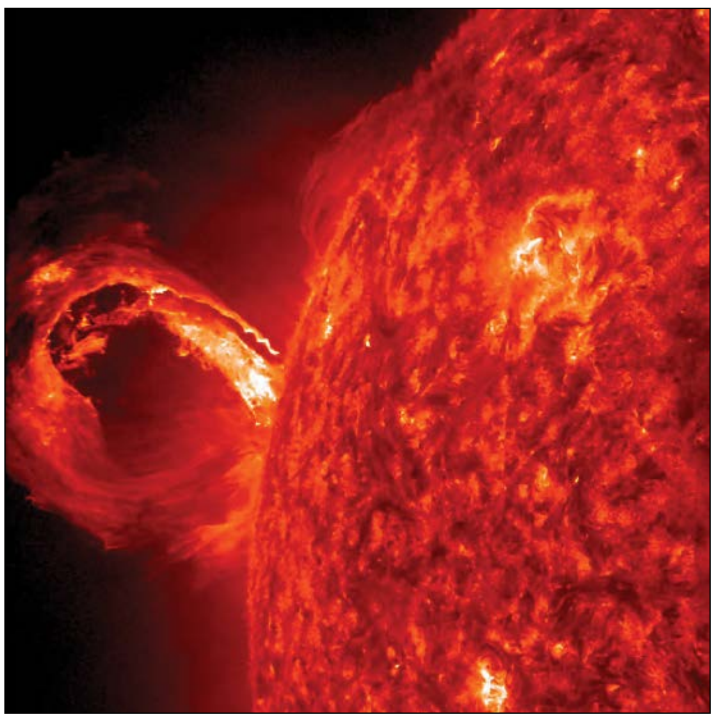
"To make organic stuff out of inorganic stuff, you need a lot of energy," said Vladimir Airapetian, an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Md. Airapetian, the lead author on a paper about the research published recently in *Nature Geoscience,* explained that perhaps that energy came from solar flares (see http://bit.ly/super-flares-life).

The new findings may also affect how researchers assess the prospects for life on worlds orbiting other stars by putting a new emphasis on young, active stars.

Solar Flares from Young Suns

For almost 10 years, NASA's Kepler telescope has been closely observing stars across the galaxy and the exoplanets that orbit them. Previous observations by the telescope have revealed that stars similar to our Sun and younger than a billion years old temporarily brightened from time to time, indicating that they released huge bursts of radiation and magnetic energy, Airapetian said. These bursts, called super flares, can be quite frequent—observers see some of these stars belching out 10 of these super flares in a day.

Using these observations, Airapetian and his team extrapolated that when our Sun was about half a billion years old, it likely bombarded Earth with a constant stream of super solar flares—up to 5 times larger than the infamous Carrington event in 1859 (see http://bit.ly/Carrington-Superstorm). That magnetic storm, the largest ever recorded by humans, knocked out telegraph operations around the world and sent the aurora borealis streaming as far south as Miami, Fla. A similar event today would cause trillions of dollars in damage to telecommunications, Airapetian said, and throw cities around the world into catastrophic power outages.



NASA/Goddard/SDO

Solar flares, the largest explosions in our solar system, took place much more frequently 4 billion years ago than today, bombarding Earth with energetic protons and radiation.

All About Energy

To find out how these super flares may have affected infant Earth, the researchers created an atmospheric model using scientists' best estimates of concentrations of different gases in the atmosphere 4 billion years ago; at that time, molecular nitrogen (N_2) was a main component of the atmosphere, along with carbon dioxide (CO_2), methane, and water vapor. They then subjected their model atmosphere to simulated super solar flares that they suspect the young Sun produced—sometimes multiple times per day—and studied what happened to the model atmosphere.

The researchers found that energetic particles associated with super solar flares compressed Earth's magnetic field and created huge gaps at the poles, which allowed highly energetic solar protons to pierce the atmosphere. Those protons knocked electrons around like bowling pins, which knocked into more electrons in an "avalanche of electrons," Airapetian said. This "avalanche" ionized atoms and tore apart existing carbon dioxide, methane, and water vapor molecules, as well as molecular nitrogen—an extremely unreactive and strongly bonded molecule, Airapetian said. The resulting highly reactive substances acted as building blocks for new substances.

"Once you have those building blocks, you have a fertile environment to start reactive chemistry," Airapetian said.

One molecule that may have formed in Earth's infant atmosphere was hydrogen cyanide (HCN)—a molecule considered vital to life's origins (see http://bit.ly/origins-solution). The newly formed HCN in a turbulent atmosphere would have dissolved into clouds and rained out, Airapetian said, likely interacting with water to form other molecules necessary for life, like formaldehyde, amino acids, and complex sugars.

This barrage of solar flares could have been like a worldwide version of the Miller-Urey experiments, Airapetian said, when scientists sparked artificial "atmospheres," full of gases like carbon dioxide, methane, ammonia, and water vapor, with electrical charges and found that this gave rise to amino acids, one of the building blocks of life (see http://bit.ly/M-Uexperiment-video).

Faint Young Sun

Another molecule that may have formed in this energized atmosphere was nitrous oxide (N_2O). You've probably heard this gas called laughing gas for its ability to calm even the most anxious dental patients.

However, "laughing gas is not a laughing matter for early Earth," Airapetian said. This nitrous oxide was important for young Earth, he said.

Although the Sun persistently showered Earth in solar flares 4 billion years ago, it was 30% dimmer than it is now. Earth should have been a ball of ice, Airapetian said, but evidence shows there was liquid water (life cannot form without it). So how did Earth heat up enough to sustain this water? Scientists call this the faint young Sun paradox (see http://bit.ly/Reviews-Geophys-FaintSun).

Today carbon dioxide drives warming of Earth's atmosphere in a big way, but 4 billion years ago, if there had been enough CO_2 in the atmosphere to heat the planet, Earth's oceans would have been too acidic for life to evolve, Airapetian said. Nitrous oxide, however, warms the atmosphere 300 times more effectively than CO_2. Even though N_2O was—and remains today—a small portion of the atmosphere, perhaps it played the major role in heating the planet, Airapetian and his colleagues propose in their 23 May paper.

The new study "is a viable additional piece in the long-scattered puzzle of how adequate supplies of biologically available nitrogen and a warm atmosphere were maintained during Earth's earliest history," said Timothy Lyons, a biogeochemist at the University of California, Riverside, who was not involved in the research. "This is an exciting idea that could kill two birds with one stone."

Implications for Extraterrestrial Life

Beyond offering new insight into how early Earth might have become a crucible for life, the new work has broader implications, Airapetian said. "Our model expands the traditional definition of habitable zones of habitable exoplanets," he noted. Now scientists can also consider exoplanets that may be orbiting young, energetic, Sun-like stars, where sufficient energy could become available to make organic molecules out of inorganic molecules.

In the habitable zone around a star, liquid water can persist on a planet's surface, but a new type of habitable zone could be termed the "biogenic zone," Airapetian said. There not only does water stay liquid, "but also the planetary atmosphere receives enough energy to make biomolecules of life, setting a pathway to [forming] RNA and DNA."

He and his colleagues are also currently studying how super solar flares could have affected Mars.

By **JoAnna Wendel,** Staff Writer

Storms Cause Infrequent Turbulence for Aircraft, New Study Finds

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Turbulence affecting air travel results from storms only about a sixth as often as other studies have estimated, new data suggest.

Past studies have found that convective storms, like thunderstorms, cause a large portion of turbulence that plagues commercial airliners. Using those findings, a research team in the United Kingdom recently set out to create an automated system for turbulence detection that relies on lightning sensors to alert airlines of dangerous winds.

Now, following the first tests of this new system, the researchers from the Met Office in Exeter have found that airplanes flying near convective storms experience much less turbulence than they expected: Just 14% of turbulence events were associated with convective storms.

This finding sharply contrasts with results of some previous studies that estimated that between 82% and 86% of turbulence encounters were associated with convective storms. The authors of the new study (see http://bit.ly/JAMC-turbulence) suggest that other sources of turbulence, such as winds forced up over mountain ranges, should receive a greater share of researchers' attention in the future. The Met Office team published its results in the May issue of the *Journal of Applied Meteorology and Climatology.*

Some turbulence researchers found the numbers surprising. The frequency of turbulence from convective storms "seems a little low, at least compared to over the continental U.S.," said Robert Sharman, an atmospheric scientist with the National Center for Atmospheric Research in Boulder, Colo., who was not involved with the new study.

The Met Office researchers used an unconventional tool to pinpoint turbulent locations: a network of lightning sensors scattered across Europe and North Africa. These sensors can triangulate the location of lightning strikes. The areas with the most lightning strikes represented the centers of convective storms, the researchers said. Comparing these data with more commonly used indicators of turbulence sources, including satellite imagery of clouds and velocity data from aboard airplanes, allowed the researchers to study the effects of turbulence from those storms on airplanes flying near them.

Sharman said he holds some doubts about the accuracy of lightning as a storm detection method, saying that lightning may not always be concentrated in the center of a storm. Moreover, he said, it's not clear "just because there's lightning that there's turbulence."

The new study's disagreement with prevailing wisdom "may also indicate that convection is relatively less important as a source of turbulence over Europe and the northeastern Atlantic than over other regions (such as North America and the tropics)," the team noted in the paper's conclusions. Many prior turbulence studies took place over North America.

However, Sharman said that it's unlikely that significantly less turbulence occurs over Europe compared with North America.

The Met Office team ran its tests for two 6-month periods (May through October) in 2013 and 2014. The researchers noted that a future study "over a significantly longer time period" would help test the validity of the patterns they found.

By **Elizabeth Deatrick,** Writer Intern; email: edeatrick@agu.org