Beyond the storm clouds

A thunderstorm may look different when seen from above

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The face of Mother Nature, when she rages with rain, lightning and thunder, can be fearsome when seen from the Earth. It can also be picturesque. But what is it like behind the face that we can see?

In a paper in the journal, *Science*, Torsten Neubert, Nikolai Østgaard, Victor Reglero, Olivier Chanrion, Matthias Heumesser, Krystallia Dimitriadou, Freddy Christiansen, Carl Budtz-Jørgensen, Irfan Kuvvetli, Lundgaard Rasmussen, Andrey Mezentsev, Martino Marisaldi, Kjetil Ullaland, Georgi Genov, Shiming Yang, Pavlo Kochkin, Javier Navarro-Gonzalez, Paul H Connell, Chris J Eyles, from Technical University of Denmark, University of Bergen, Norway, University of Valencia, Spain and National Institute for Astrophysics, Bologna, Italy, go into aspects of thunderstorms that are best seen from the fine weather there is well above the storm. Aircraft cannot usually fly high enough to get there, and need to stay away. But the authors of the paper make use of satellite observations, and find that high voltage lightning, during a thunderstorm, powers ultraviolet emissions and even gamma rays, up in the ionosphere.

Thunderstorms, which are also known as electric storms, are marked by lightning and thunder, usually accompanied by winds and rain. They occur in clouds called cumulonimbus, which form in the lower part of the atmosphere (where the temperature falls as one goes higher) but grow vertically, as high as 20 km. Due to processes within clouds, there is separation of particles into lighter, positively charged particles, and heavier, negatively charged particles. The lighter, positively charged part migrates to the top of the cloud, while the lower end is negatively charged.

Very high charges can build up, with differences in millions of volts, and there is electric discharge — from different parts of a cloud, from one cloud to another or from a cloud to the ground. These discharges are the strokes of lightning and they represent huge transfer of electrical energy. Very high temperatures are reached and the rapid expansion of air is heard as thunderbolts. The electrical discharge leads to ionisation, or the splitting of atoms of air into positive and negative parts, and chemical reactions, and the discharge can interfere with radio communication.

While the visual effects of this activity are spectacular, what goes on within the kilometres-high pile of cloud, and then the upper reaches of the atmosphere above the cloud, are hidden from view. There had been isolated references, for example by explorers atop high mountains, above the clouds, who saw flashes of light that rose upwards from the clouds below. Much later, in the 1920s Scottish physicist CRT Wilson theorised that electrical breakdown should occur in the atmosphere high above large thunderstorms. Highflying aircraft also noticed electrical discharge above clouds but it was only in 1989 that weak luminous flashes above a thunderstorm, at the same time as a cloud to ground lightning stroke, were photographed.

These flashes are reddish-orange flames with hanging tendrils, or circular doughnut shapes, or greenish-blue streaks, many kilometres across and rising 50 to 90 km above the Earth's surface. Lasting just a fraction of a second, these Transient Luminous Events — or TLEs as they are known — have been evocatively named jets, sprites and elves. Blue jets are seen in the stratosphere, 10-20 km high, where the atmosphere starts warming as we go higher. They propel upwards, can rise some 12 km above a thundercloud, and are not associated with a downward lightning stroke. And along with them are flashes that are called trolls, gnomes and pixies. Red sprites are found 25-55 km above the cloud and their tendrils can hang by 25 km. Elves are doughnut-shaped flashes over 250 km across and generated by the current that flows during lightning strikes and are the most frequent TLEs.

In 1994, Nasa's Compton Gamma Ray Observatory, in a 450 km orbit around the Earth, discovered flashes of gamma rays coming from the atmosphere. Terrestrial gamma ray flashes (TGFs) are brief (just a few thousandths of a second) emissions of high-energy photons, and they were observed when the satellites passed over thunderstorms. The energy of the photons reached that of gamma rays, which arise from interaction of high-energy cosmic ray particles with the atmosphere or in nuclear reactions. It was suggested that TGFs arose from high-altitude TLEs, the paper says, but it was found that their source was within thunderstorm clouds.

Now, it is understood that high-energy photons are emitted when electrons are accelerated by the gigantic electric fields in thunderclouds or lightning flashes. It is a property of electric charges that they emit electromagnetic radiation, or light, when they are accelerated. Atmospheric gamma rays arise when charged cosmic ray particles are deflected when they pass near the nuclei of atoms in the atmosphere, a process called *bremsstrahlung* or braking radiation. The conductivity of air comes more from electrons that are set free by cosmic ray particles interacting with the atmosphere. Electrons, being lightweight, experience high acceleration, to speeds near that of light. In the process, they emit gamma rays, apart from setting free other electrons, which join the torrent.

The team writing in *Science* used the data from the Atmosphere Space Interactions Monitor, which is on board the International Space Station, the orbiting research facility managed by the American, European, Russian, Japanese and Canadian space agencies. The Monitor observed a TGF produced in the initial stage of a lightning flash, east of Indonesia. The monitor has two x-ray and gamma ray detectors, three ultraviolet and optical photometers, and two optical imaging cameras, all pointed directly downward, the paper says.

The cameras observed and recorded the entire sequence of emissions before and during lightning flashes, in the optical, ultraviolet and gamma ray regions, in conjunction with atmospheric data, such as cloud altitudes, from ground-based facilities. The timing of the optical, the ultraviolet and TGF activity, measured correct to microseconds, showed how the ultraviolet, X-ray and gamma ray emission, and TLEs, like elves, kept pace with the rising lightning current.

"The TGF occurred at the onset of a lightning current pulse that generated an elve, in the early stage of a lightning flash", the paper says and "The observations provide evidence that there is a connection between TLEs and TGFs." A glimpse "backstage" of thunderstorms is perhaps an indicator of what is going on at the surface of a distant, cloud covered planet, from the upper atmosphere theatrics that are visible to us.

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Unicorn of the sea

Given their unique anatomies, narwhals have intrigued people for centuries

KRISTIN LAIDRE

Narwhals are often called the unicorns of the sea. The long tusk of the male narwhal sets these whales apart, but it's not the only thing that makes *Monodon monoceros* among the most intriguing and mysterious marine mammals.

A deep-diving cetacean in the odontocete family (which means "toothed whales"), narwhals live in cold Arctic and sub-Arctic waters. They're highly adapted to living in areas almost completely covered with sea ice. Narwhals are among the only whales that live in areas with such dense sea ice cover for up to six months each winter.

As a scientist who studies animal ecology in the Arctic, I know firsthand that seeing a narwhal in the wild is a special experience. They usually travel in pods and can be quite sneaky. When they pass by, you may only see a small sliver of their mottled black and white skin above the water when they surface to breathe. No wonder glimpses of these whales and their unique tusks have fuelled myths for centuries.

The tusk that is the narwhal's claim to fame

Unlike all other toothed whales, the narwhal actually has no teeth in its mouth. Instead, the male develops a long straight tooth, called a tusk, which protrudes six to 10 feet out of his upper left jaw. A long tusk on an adult male can be more than half the usual total body length of about 16 feet. The tooth grows in a counterclockwise spiral — nature's only spiral tooth.

The tusk is essentially unique to male narwhals. Very rarely, a female will grow a tusk, or even more rarely a male narwhal will grow two. Tusks exported from the Arctic, perhaps by the Vikings, reached Europe, the Mediterranean and even the Far East as early as the Middle Ages and became the source of the unicorn myth. The tusks were sold to the very rich without a good description of the animal from which they came and inspired a great deal of fantasy.

To some extent, tusks still inspire fantasies, as people have proposed many unsupported explanations for their purpose — whether breaking ice, sword fighting with other whales, spearing or smacking fish for food, sensing temperatures or digging in the bottom the sea.

One thing is clear: The tusk cannot serve a critical function for narwhals' survival, because females, who do not have tusks, live just as long as males. And they do it surviving in the same harsh areas, finding the same food and additionally being responsible for reproduction and calf-rearing.

The tusk is a sexual trait, much like the antlers of a stag, the mane of a lion or the feathers of a peacock. Males use the tusk to determine social rank and compete for females. It is not entirely clear how this works, but male narwhals may be able to visually size each other up as competitors; they may interact with their tusk with some unknown level of aggression underwater; or possibly a female could use the tusk as a visual signal for choosing her mate. During the summertime in the northern Arctic bays and fjords, male narwhals can be seen interacting at the surface, carefully crossing their tusks and touching them together. Such behaviour might help adult males compare themselves and maintain dominance hierarchies. Or perhaps it helps young males nearby learn skills necessary for performance in adult sexual roles.

A Danish coronation chair from the 1600s is made of narwhal tusks and Right A pod of narwhals in Northwest Greenland.

Living in a changing Arctic

Narwhals' extensive migrations follow the formation and retreat of annual sea ice. Some can travel thousands of miles in a single year.

The over 100,000 narwhals worldwide today are divided into subpopulations of between a few thousand to up to 30,000 animals, based on where they spend the summer, in ice-free bays and fjords or at glacial fronts. In autumn, they migrate to overwintering areas that are deep, offshore and ice-covered, usually along the continental slope. Most feeding takes place in winter, and then females give birth in spring.

During the winter months in the dense pack ice, narwhals can make dives that are over a mile deep, sometimes swimming upside down as they descend into pitch black water. They sometimes seek prey close to the bottom, such as Greenland halibut, and swallow them whole.

Narwhals are part of an Arctic environment that is rapidly changing. The region is warming twice as fast as the rest of the world —1.35 °F (0.75°C) in the last decade alone. By comparison, it's taken the Earth as a whole the past 137 years to warm by nearly the same amount, 0.8°C.

In order to understand how narwhals may or may not adapt to the climate change in the Arctic, it is vital to develop a basic understanding of their ecology. Furthermore, narwhals are an important cultural, nutritional and economic resource for native communities in Greenland and Canada.

My colleagues and I are continuing to study the structure and dynamics of narwhal populations in a changing climate, in hopes we can conserve their populations and ensure they remain sustainable biological resources.

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PLUS POINTS

Life on Mars

The water on Mars appears to have been an especially good home for life, according to a new study. Previous studies have suggested the red planet would once have been home to lakes of flowing water, which could have been home to life. But there has still been no evidence to suggest that alien life once lived on the planet — or that there is any evidence of it there still.

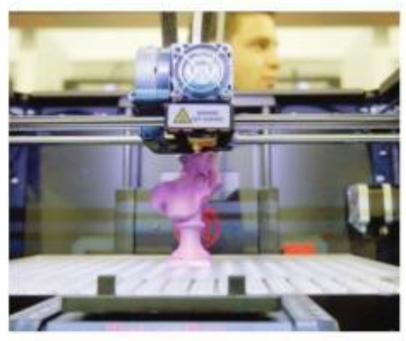
In an attempt to understand what the ancient Mars could have looked like and whether it was inhabited, scientists have looked to understand the water chemistry that would have been found on the planet billions of years ago. They do so by looking at the materials left over on the planet today, which could offer a clue to how it once looked.

Recent measurements taken by Nasa's Curiosity rover on the Martian surface suggest that the water that is thought to have once covered its surface could have had just the right ingredients to support any microbial life that formed on the planet.

The new study looked at sediments that seemed to have been left in lakes on Mars's Gale Crater. It found they appeared to have formed in the presence of liquid water that had a similar pH to that in Earth's oceans. That suggests that the early surface of Mars would have been the kind of place that could have served as a home for life, like that on Earth.

A paper detailing the discovery, titled "Semiarid climate and hyposaline lake on early Mars inferred from reconstructed water chemistry at Gale", was published in *Nature Communications*.

The independent



3-D solutions

Researchers from the University of Sheffield in the UK have, for the first time, manufactured 3D printed parts that show resistance to common bacteria. This could stop the spread of infections such as MRSA in hospitals and care homes, saving the lives of vulnerable patients.

The study was published recently in *Scientific Reports* by an interdisciplinary team of researchers from the University's department of mechanical engineering and the School of Clinical Dentistry. The research combined 3D printing with a silver-based antibacterial compound in order to produce the parts.

Results from the research have shown that the anti-bacterial compound can be successfully incorporated into existing 3D printing materials without any negative influence on processability or part strength, and that under the right conditions, the resultant parts demonstrate anti-bacterial properties without being toxic to human cells. Further work is ongoing to investigate the full extent of this capability.

The findings offer the potential for applications in a wide range of areas, including medical devices, general parts for hospitals which are subject to high levels of human contact, door handles or children's toys, oral health products (dentures) and consumer products, such as mobile phone cases. Further projects are planned in each of these areas, with an aim to work with leaders in industry.

Products such as medical devices are often already coated with an antibacterial compound and are subject to strict and rigorous cleaning or sterilisation procedures. However, whilst this provides a certain level of protection, they have their limitations, such as human error in cleaning or damage occurring to the coating.

Rigorous testing and imaging techniques were carried out to establish the effect of the antibacterial additive — looking at the effect on the quality of the final part, its mechanical properties and whether it survived the manufacturing process. Parts with and without the antibacterial additive were submerged in various bacterial solutions to test how many bacteria remained after 24 hours. Parts containing the antibacterial additive were effective against examples of the two main groups of bacteria, Gram positive (*Staphylococcus aureus*) and Gram negative (*Pseudomonas aeruginosa*), both of which can cause many different types of infection.