

Future Clouds: diatoms, speculation and weather modification

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Abstract: This article uses diatoms and the role they play in cloud formation as a prompt to consider histories of weather modification in practice, science fiction and possible future applications to address climate change. Diatoms are a form of microalgae that are present in all waterways and contribute significantly to atmospheric oxygen. They also provide condensation nuclei around which water droplets form, effectively creating clouds. Such naturally occurring particulate matter interacts with intentional and unintentional anthropogenic influence on the atmosphere. The long history of folk speculation and scientific experimentation about effective ways of seeding clouds for rain can help us consider the potential impacts of new forms of atmospheric intervention. From the use of algae as a tool for bioremediation to marine cloud brightening techniques, a multiscale ecological awareness needs to be publicly fostered in making choices about how to influence climate futures.

Keywords: diatoms, algae, cloud formation, climate futures, atmospheres

Grains of Stone

“That which is above is like to that which is below, and that which is below is like to that which is above.”
(Steele R. & Singer 1928, 486)

This quote is an extended English translation of the much paraphrased line ‘as above, so below’ attributed to Hermes Trismegistus and his ancient treatise known as the *Emerald Tablet*. Such ancient celestial speculation so popular with alchemists and occultists may not be as influential today but it is a reminder of the interrelations between the sea and sky, the atmosphere and land.

These days, we rely on other tools to make sense of atmospheres. On one level, this might involve just a quick Google search or glance at a weather app to see news about the coming week. At another scale, there is peering into the deep time of climate futures, of possible natural disasters and global catastrophes. If we turn away from our screens for a moment and look back at the sky, we might be surprised to see algae play a previously overlooked role in shaping the clouds on the horizon.

Recent research has discovered the prevalence of a wide variety of algae, diatoms and microbes in the atmosphere. This organic matter in the atmosphere contributes to the density of cloud formation. In one study, researchers collected cloud and rain water samples from around Puy de Dome Mountain in central France and found a diverse collection of living microorganisms (Dillon et al. 2020). In framing the importance of their study these researchers emphasize a better understanding of, “these aeolian dispersed organisms is needed to understand their ecology, as well as how they could affect ecosystems and human health” (2020, 1). Another study has shown how atmospheric aerosols, including fresh water diatoms, from Africa are born through trade winds to the western equatorial North Atlantic Ocean where they play a significant role in contributing iron into the marine ecosystem. The prevalence of aerosolized organic matter in the atmosphere has also been studied in terms of the influence of virus infections on phytoplankton (Diaz et al. 2023). Viruses play a role in how much organic matter is subsequently turned into cloud condensation nuclei (2023).

An example of such viral infections and their effect on cloud formation can be seen in the diatom known as *Emiliania huxleyi*, or *E. huxleyi*, a single-celled phytoplankton. *E. huxleyi* surround themselves with coccoliths, or ‘grains of stone,’ calcium carbonate plates that together form into a coccosphere. Viral infection of *E. huxleyi* "leads to bloom demise and results in *E. huxleyi* cell death and enhanced shedding of coccoliths into the seawater." (Trainic et al., 2018, p. 328). Some of these shedded coccoliths drift down to the seabed while other broken and discarded coccoliths make it into the atmosphere, tossed skyward by sea foam and waves (2018). These tiny, light coccoliths then drift around in the currents of the atmosphere. Caught up in the wind, they provide surfaces for condensation to form and therein help create clouds. Paradoxically they can also have the opposite effect, breaking up clouds and preventing rainfall.

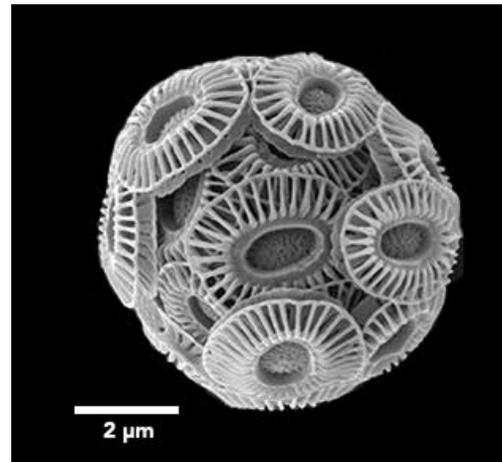


Figure 1 - *Emiliania huxleyi*

As an anthropologist interested in parallels between folklore, mythology and the history of science, learning of this role diatoms play has led me to wonder about past and future attempts to influence the weather. In folk traditions, a whole variety of rituals, dances and customs, have been used as proactive measures to call for rain in the face of drought. In the Balkan peninsula there are a variety of related practices for rainmaking. In Bulgaria, the practice known as *peperuda* (butterfly) involved a young woman dressed up in a costume made from plants who then travels door to door in the village with the community pouring water on them (Petroff, 1957). James George Frazer writing in *The Golden Bough* (1889), would call such practices ‘sympathetic magic’ pointing out that they rely on imitation or a logic of contagion to be effective. Frazer’s attempt to create a comparative catalog of magic, dedicates a chapter to ‘The Magical Control of the Weather.’ Subsequent scholarship has rightly critiqued the armchair Eurocentrism of Frazer’s interpretation of indigenous practices as ‘failed science’ (Kumar 2016). As seen in the work of Michael Taussig, there is still a need to think through the mimetic powers of magic, ritual and images (Taussig 1993). Whether such traditional practices are effective triggers of precipitation is not really the point. What is important is that they are expressions of atmospheric attunement and part of a common cause to try and understand and influence the weather.

This diverse global history of folk rainmaking traditions predicts later scientific attempts to understand cloud formation. The relationship between such speculation and science can be more a continuum than

a clear cut boundary. Speculation about the world can be a spur that prompts more rigorous scientific investigation. Even though looking at clouds in wonder is a common childhood memory, most of us don't go on to pursue degrees in meteorology; nonetheless, that initial sense of wonder and curiosity can fuel continued study of the atmosphere.

Speculative History

Knowledge of the role diatoms play in cloud formation comes after a long line of speculation and largely unsuccessful attempts to deliver on the promise of weather manipulation. In the 19th century, 'rainmakers,' charlatans, and confidence men traveled the arid regions of the North American west and Australian outback, with elaborate elixirs and contraptions meant to seed clouds with rain for ailing crops. While largely ineffective or at best inconsistent at curing drought, these early interventions into the atmosphere did unwittingly predict the importance of cloud condensation nuclei such as the coccoliths of diatoms.

Clement Wragge, an Australian meteorologist, put his weight and reputation behind the 'Steiger Vortex' a conical device he had seen used in Austria to disperse clouds that threatened grapes still on the vine with destructive hail. Wragge manufactured his own large rainmaking canons in Australia as a means of combating the drought that was affecting Australia at the time. Unfortunately, when they were fired in 1902 they didn't have the desired effect with a couple even exploding. Wragge attributed this to too much explosive being used and a lack of a consistent firing routine (Sinnamon, 2017). The fact that each 5-meter-tall device was labeled with the names of the key parties involved, Wragge, Stiger, Philip, Harvey, Suschnig or Leahy, surely added to the ignominy of this failed experiment. Nonetheless, the knowledge that the addition of particulate into the air could trigger participation was part of the best understanding of cloud formation at time.

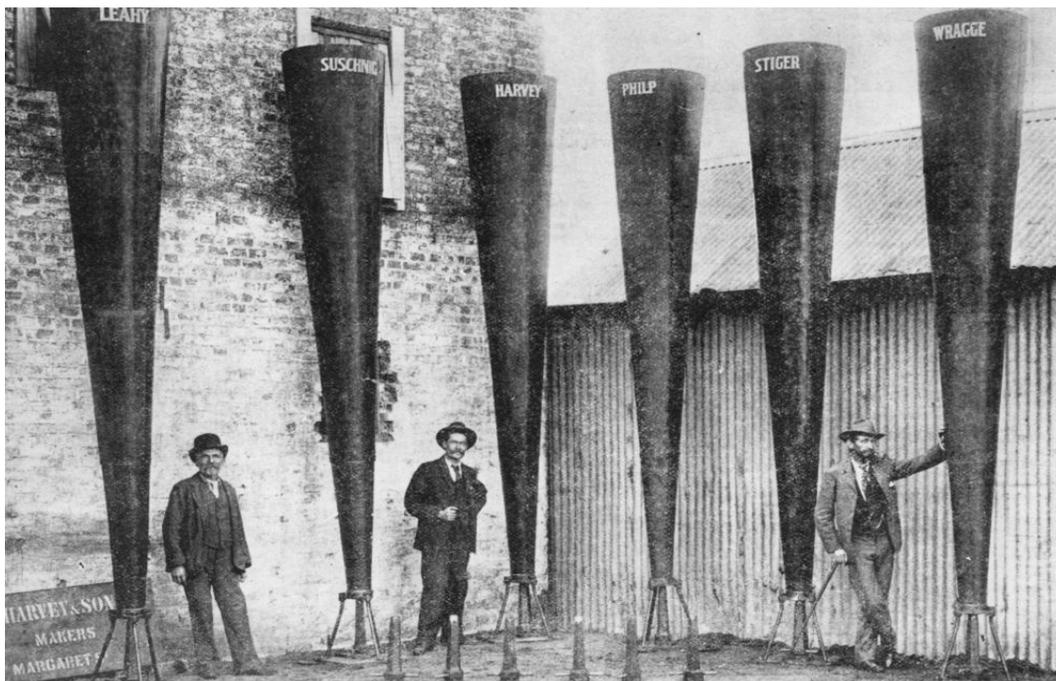


Figure 2 - Battery of Stiger Vortex rain-making guns at Charleville, Australia 1902

In his book *Rain Produced at Will* published in 1891, Louis Gathmann first outlines the science of seeding clouds, a theory that he could not implement at the time but that would later be put into practice. Gathmann foresaw techniques for fog dispersal that could save ships edging too close to shore and clear London's legendary fog. Cloud seeding was seen as more than just an agricultural concern. It was also not always an innocent act. It has been used by states as a tool of war and propaganda as well as a way to mitigate the effects of drought and storms. During the Vietnam War, 'Project Popeye' was a US military project designed to prolong monsoon rain along the Ho Chi Minh trail with the aim to reduce the mobility of North Vietnamese troops (Darack, Ed. 2019). Before the Beijing Olympics in 2008, the Beijing Weather Modification Office used rockets to release silver iodide into the skies outside of the city, in order to keep the opening ceremony free of rain. This practice, known as 'blueskying,' is aimed at bolstering China's internal profile when hosting large scale events and foreign dignitaries (Chien 2019).

The U.S. government's project to influence the weather began in collaboration with GE (General Electric). This joint project known as 'Project Cirrus,' grew out of earlier study of aerosols and began with a stated initial goal of finding a solution for de-icing airplane wings. One of the research associates in the project, Dr. Vincent J. Schaefer, later chanced on the discovery that dry-ice could be used effectively as a technique for cloud seeding. Initial experiments in the lab with dry-ice (carbon dioxide in its frozen form) were soon after put into practice with the first successful seeding of snow fall over Mt. Greylock Massachusetts in 1946 (Tietz, 2022). The project subsequently evolved into an attempt to alter the path of, or otherwise modify, hurricanes using silver iodide as a form of artificial cloud condensation nuclei. This hurricane focus was stalled soon after but taken up again with 'Project Stormfury' in 1962. Experiments with anthropogenic weather modification work much like coccoliths, sand, and other naturally occurring particulate matter; by introducing more particulate into the atmosphere they create more nuclei on which condensation can form.

These early weather modification experiments also have an interesting parallel with and influence on science fiction. Kurt Vonnegut's brother Bernard Vonnegut played a leading role in the GE project. Kurt Vonnegut, himself, also worked for a period as an in-house writer for GE. He later incorporated a speculative version of these weather experiments in his novel *Cat's Cradle* (1963) in the form of 'cloud-nine' a military developed substance that could turn water into ice at room temperature.

In science fiction we find a whole host of gaseous clouds and atmospheric effects that were used to control people, the planet and alien worlds. In H.G. Wells' influential *The War of the Worlds* (1898) extraterrestrials use a variety of tools to exterminate earth's population with one of them being canisters of 'black smoke.' M.P. Shiel's *The Purple Cloud* (1901) chronicles an expedition to the North Pole which unleashes a deadly purple cloud that spreads around the world to devastating effect. In the 1957 scifi novel *The Black Cloud* author Fred Hoyle tells of a giant sentient black cloud that comes to rest in between the earth and sun threatening all life on earth. In more recent *clifi* (climate fiction), the threat no longer comes from other worlds but instead from the out of control impact of human life on the environment. In Neal Stephenson's *Termination Shock* (2021), cloud formation on a global scale is proactively used to stave off the effects of global warming by increasing the albedo or reflectivity of clouds against solar radiation. The termination shock of the title refers to the disastrous effects of such solar geoengineering if they are not maintained and abruptly stop. In Kim Stanley Robinson's *Ministry of the Future* (2020) waters around the North Pole are dyed yellow to effect their albedo and thereby help stay iceberg melt and in his Mars trilogy of books he considers the terraforming of Mars and the challenge of making it hospitable for human life.

These more recent science fiction scenarios both predict and warn about the unintended impacts of geoengineering. Part of the appeal and temptation of weather modification is that it can be bounded and controlled. What if we were able to wield the power of diatoms to create localized weather? The perpetual rain cloud pictured above a particularly grumpy cartoon character could be a reality. Like the enclosed microclimates of greenhouses, control of specific small areas of the atmosphere might also be useful in tending to future crops and gardens, but at what cost?

Experimental futures

Recently researchers off the coast of Australia have experimented with the first use of cloud brightening technology to combat coral bleaching (Bay et al. 2019). The trial worked by atomizing seawater to turn bits of sea salt crystals into cloud condensation nuclei. These thickened and in turn more reflective clouds bounce more sunlight away from reefs suffering from higher water temperatures. While the long term impact of such localized marine cloud brightening is not known, it is no longer just the stuff of science fiction.

At the same time as it is important to be wary of any unintended ecological impacts of geoengineering it is also necessary to keep these separate from conspiratorial visions of secret government weather manipulation campaigns. Such conspiratorial thinking still abounds in theories of so-called ‘chemtrails.’ Conspiracy theorists believe that contrails, the clouds formed in the wake of airplane engines are part of a sinister government conspiracy to poison and control the general population (Tingley & Wagner, 2017). In fact, such contrails are simply ‘homogenitus’ as classified by the World Meteorological Organization in the *International Cloud Atlas*. They are a kind of anthropogenic cirrus cloud without any malevolent agenda. Such clouds are also visible in the exhaust from shipping boats and a source of inspiration for new ideas about how to combat climate change. Researchers have speculated on using hundreds of so-called ‘albedo yachts’ circulating around the world’s oceans (Latham et al., 2012). These boats would emit atomized sea spray to create new cloud cover and cool off the planet.

The ethical dimensions of such geoengineering have been taken up earlier by none other than Wilhelm Reich, Freud’s protégé and infamous theorist of orgone energy. Reich was invested in trying to solve the problem of desertification which he believed was brought on by ‘DOR (deadly orgone radiation).’ To combat this process, Reich developed his ‘cloudbuster’ device. Developed in the 1950s and later immortalized in Kate Bush’s song ‘Cloudbusting,’ the device used long tubes to draw Reich’s theorized orgone energy out of bodies of water and pass it into the sky at Orgonon, his farm and research center in the US state of Maine.

Reich, while wrong about the mechanism of cloud formation, did show a real intuition as to the interaction between clouds and bodies of water. We are left to wonder what Reich would have made of the revelation that algae is more of a connective element than orgone energy. One thing Reich did leave us with is a manual or manifesto on the ethics of geoengineering. He published his own *Rules to Follow in Cloud Engineering* in 1954. The 15 rules begin with the rather direct admonishment to “Shed all ambition to impress anyone” (Reich 1954). Alongside a whole variety of safety warnings he also includes a reminder that “In cloud engineering you do not ‘create rain,’ - you do not ‘destroy clouds,’ - briefly, you are not playing God. What you do is solely helping nature on its natural course” (1954). The ethical and safety concerns in Reich’s imagined cloud engineering presage debates around solar geoengineering

and other proposed solutions for global warming. Reduced to a simple maxim, one must be careful about the unintended impact of proposed solutions.

This history of cloud busting and weather manipulation isn't just a story of failure and fantasy. These speculative devices hold grains of truth and spurred future variations that ultimately proved more effective. Looking to future projects, we can consider how diatoms might help us think about links between the sea and sky in new ways. What strange devices might be created to draw them out, to disperse them in the atmosphere or spread them out into new environs?

In fact algae, in their many forms, already play an important role in water cycles and the atmosphere. With their intricate silica outer layers, diatoms contribute significantly to atmospheric oxygen and sequester carbon dioxide carrying some of it into the deep sea. They were also once a source of wonder for hobbyists in Victorian Britain, who carefully arranged them into microscopic patterns, some of them presumably more interested in their visual characteristics than their role in the environment. More recently, they have also been studied as tools for bioremediation in the removal of heavy metals from polluted waterways. International researchers working with the Royal Netherlands Institute for Sea Research have experimented with diatoms as an alternative to other bioremediation processes reliant on large amounts of fresh water (Hedayatkhan et al, 2018). A byproduct of the process is the creation of lipids that could serve as potential biofuel (2018). Diatoms have also been studied by a trio of Indian biologists, Thomas Kiran Marella, Mallimadugula Venkata Bhaskar and Archana Tiwari, as a remediation solution for eutrophication or the presence of too many nutrients in freshwater lakes due to fertilizer runoff (Marella et al, 2016).

With just a bit of speculative imagination we can begin to envision a near future where diatoms are used to seed clouds in a form of atmospheric bioremediation. Taking inspiration from this latest research on algae and historic cases of cloud seeding, such an imagined future is a chance to consider the biological, political and social implications of algae bioremediation both at sea and in the sky.

In considering future prospects of such intervention into the climate, we might learn a lesson from *E. huxleyi*. We can build protective walls and environments around ourselves but we would do well to remember that these materials will outlast us. Like the remnants of coccolith spheres, they will stick around and find their way into waterways, winds and atmospheres. They will impact the peoples, algae and clouds of the future.

Thinking at scale

Controlling the weather may be the wrong way to be thinking about future clouds and climates. Instead of devices and tools to empower bioremediation of atmospheres and waterways with algae, perhaps we should be simply trying to think of new means of being able to see the microscopic and multiscale connections already happening in multispecies worlds. Being able to both see and narrate these relationships is one of our biggest challenges. How can we predict the future if we can't even see it?

Science fiction, folk practices and popular science scholarship can all help us begin to see and take note of the vast scale of interrelationships between the microscopic and the global, between things too small to see and things too big to see. Multiscale stories are needed to help us comprehend our intended and unintended anthropogenic influence.

A good example of this kind of public science storytelling comes from the British biologist and anthropologist Thomas Henry Huxley, for whom *E. huxleyi* are named. He famously used his lecture in 1868 entitled ‘On a Piece of Chalk,’ to inspire a general audience in Norwich, England to think about diatoms. He directed the audience to consider the very earth beneath their feet and how it was formed over millennia through the slow collection of a mass of coccoliths on an ancient sea floor. Under that audience were the same white chalk deposits that are on display at the Great Cliffs of Dover, deposits that stretch all the way to continental Europe. Those hulking white cliffs of Dover are also made of some of the same matter that floats above them, creating microscopic cloud condensation nuclei around which water droplets form causing clouds to appear. They are also made of the same stuff as the professor’s chalk, a finite resource hoarded by mathematicians and other academics who have come to rely on the chalkboard as a primary tool of scholarship and education. These are the kinds of interrelationships that we need science scholarship and good stories to understand.

In spite of the best efforts of Huxley to make the general public aware of diatoms, *E. huxleyi* and other diatoms remain largely absent from the public imagination. Perhaps it is because individually they exist at a microscopic scale where they can be easily overlooked and ignored. They do, however, also collectively form into large algae blooms that can be seen from space. Their silica based coccolith shells reflect sunlight creating huge swaths of aquamarine waters, swirls of color more associated with tropical seas than the North Atlantic. These massive algae blooms change the albedo of the water, transforming how much sunlight is reflected back. Clearly, diatoms have a large impact even if their net effect on the climate is not precisely known by scientists or acknowledged by the general public.



Figure 3 - *Emiliana huxleyi* bloom off the coast of France

Into this gap in understanding and awareness, there is a place to try again to imagine new devices and means of drawing public attention to the diatoms beneath their feet and aloft above them. Conspiratorial worries about government seeding of clouds can be turned into a proactive collective reimagining of what part we all might play in creating sustainable climates and new clouds in the future.

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