SHAPING ATMOSPHERES: FROM TERRAFORMING LAND TO GEOENGINEERING AIR

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The malleable materiality of the earth invites the possibility of terraforming the planet. Throughout history, significant interventions in our Earth's ecosystems have left territorial and infrastructural imprints. Such planetary alterations have played a pivotal role in our cultural evolution, making possible the explosive propagation of the human species and driving developments across diverse fields, ranging from agriculture to art. Today, amid the rapidly changing climate and mounting concerns for the air, our attention shifts from 'terra' to 'atmos', with a focus on the significance of *shaping atmospheres*.

Under a thick planetary sky, we grow more attuned to the viscosity of air.[1] Once regarded as a universal aether impregnated with myth and imbued with astrological significance, carrying spirits and ghosts, the sky now bears the burden of heat-trapping gasses and erratic weather. These atmospheric alterations pose a formidable threat to the planet's ecosystem, endangering the very breath of life for most living beings. In these desperate times, recent attention has turned to new geotechnologies, such as solar geoengineering that artificially reconditions the stratosphere and mitigates heat from solar rays.[2] As a result of such drastic interventions, the once familiar sky could undergo profound transformations, both in its material composition and in the place it occupies in our collective imaginary.

From our vulnerable position, our gaze once again ascends skyward, echoing an age-old yearning that reaches towards the heavens and the boundless universe for answers. Throughout prehistory and our earliest civilisations, the heavens provided the constant in a tumultuous world. Capturing the significance of the sky in human history, John Durham Peters describes the heavens as 'a source of legitimacy, meaning, and orientation', functioning as 'a compass, calendar, and clock'.[3] The clockwork of the heavens was mapped and interfaced with megalithic structures and early temples, while star mapping presented the first attempt at large data collection and pattern recognition to make meaning. At the same time, the sky delivered the ficklest of fates: floods, hailstorms, fiery meteorites and other plagues from the gods. Less a spatial separation (which today we understand as a spectral range between astronomy and meteorology), the ancient world was divided into the *above*, where phenomena remain *constant*, and the *below* where phenomena *fluctuate*. In the earliest creation myths, such as Sumerian and concurrent lore, the origin of the world required a similar separation of the atmosphere, land and sky had to be pulled apart. Genesis recounts the creation of the firmament as a separation of the waters into *above* and below the domed arch of the sky. The Babylonian creation myth *Enuma Elish* tells the story of the goddess Tiamat, who forms a protective layer in the sky, stretching over the watery heavens and sealing off the earth.[4] Religious practices also required spells to sustain such a place for humanity to survive. For instance, the Egyptian *Book of the Dead* (c.1500 BCE) depicts an ibis-headed Thoth holding up the sky-layer with pillars, providing vertical space to enable air underneath.[5] In these myths, the air we breathe must

Previous spread:
Robert Smithson, *Spiral Jetty*, 1970.
Photograph: Charles Stankievech

be safeguarded from the unknown dynamics of the sky, so as to prevent suffocation from the vast expanse above – a powerful reminder, today, of the need to sustain an atmosphere.

Drawing inspiration from such myths, civilisations developed early forecasting practices to protect themselves. These included tracking cloud formations or calendars dividing the year into cyclical parts. During the sixth century BCE, the Babylonians embarked on attempts to forecast immediate weather changes, relying on observations of cloud formations and optical phenomena like haloes. In the third century BCE, Chinese astronomers crafted a calendar dividing the year into twenty-four festivals, each linked to specific weather patterns. Continuing this empirical tradition, but with a more rational approach, around the fourth century BCE, Greek philosopher Aristotle authored *Meteorologica* (c.340 BCE), a foundational proto-scientific and philosophical work encompassing theories on the origin of rain, clouds, hail, thunder, lightning, and of course the titular *meteors* (here classified as a weather phenomenon due to their mercurial status). As philosopher Dehlia Hannah observes, 'Meteorology contends with the unstable epistemological territory of natural irregularity.'[6] However irregular and untameable environmental forces may be, humanity was compelled to track the sky, leading to the discovery of predictive patterns. As a collective practice, gathering information from the sky has been integral to the survival of our species. Lorraine Daston, in *Histories of Scientific Observation*, highlights the important history of the 'slow accumulation of anonymous observations over generations, centuries, even millennia.'[7] Such collective efforts were encoded in folklore and myths, constructing oral remembrance that also possessed explicative power. Connected to the same sky, every human becomes part of this sensory process, holding knowledge of the ever-changing medium we are immersed in, and passing information on across generations.

Technological advancements significantly revolutionised these practices of information gathering. With the advent of computers, a momentous leap occurred in collective observation and exchange, offering platforms that facilitate the accumulation of data on an exponentially larger scale, in real-time, and across the globe. This computational shift enabled for the first time a truly global modelling of weather. Initially conceived by the military to control and sustain air warfare, the development of electronic digital computing began as a collaboration between American military research agencies and the US Weather Bureau around 1948.[8] It is not a coincidence that the subsequent Cold War borrowed more than just temperature adjectives as it cloaked its military endeavours under the semiotics of weather.[9] MIT's *Whirlwind* computer forged the birth of cybernetics evolving into the SAGE/DEW network under the cover of classified 'weather stations' in the Canadian Arctic such as CFS ALERT.[10] It is worth noting, however, that a feedback loop (reminiscent of the original design of these systems) has short-circuited: the Pentagon acknowledged in 2007 that climate change would be a growing defence issue, what one of the co-authors, Charles Stankievech, has dubbed as the coming 'Warm War'.[11] While the military might have originally generated the processing power for modelling the climate, today there is a pressing need for global climate modelling, simulation, and prediction to address the complexities of climate change beyond military purposes.[12] The essential aspect of this endeavour is the capacity of a vast system

to capture the continuous sky not as discrete fragments of regional weather patterns but as a planetary climate, interconnected within a web of complex concerns. Advancements in data gathering and processing infrastructure facilitated the establishment of a collective network first through longwave microwave and then satellites. These collective systems, which continue to include the human as essential element, form a global infrastructure capable of gathering and processing information *produced within* and *transmitted through* the sky.

Along with advancements in sensing the sky and the illusion of mastery through prediction, the twentieth century also saw an alarming weaponisation of the atmosphere. In step with the development of novel defensive architectural forms, a direct attack on breathable air was inaugurated with the first instance of gas warfare in World War I. In *Bunker Archéologie* (1975), Paul Virilio describes the pivotal moment in the strategy of conflict when a 'total war' was waged that 'competed successfully with natural forces', by assaulting not the enemy directly but their *environment*. A new landscape was thus forged where 'firearms, explosives, smoke screens, and gases have contributed to the creation of an artificial climate'.[13] Building on this harrowing reality, Peter Sloterdijk defines this turn as 'terror from the air'.[14] This shift in the nature of warfare put an emphasis on the manipulation and control of the atmosphere as a means of inflicting harm and exerting dominance. It is no surprise that both Virilio and Sloterdijk contrast this atmospheric warfare to their architectural and spatial analysis of hermetic spaces, respectively, the underground bunker and the inoculated bubble.[15] The poisoning of the outside required the architectural invention of the pure inside (both technically and ideologically).

After World War II, the rapid development of atmospheric control technologies continued within the looming context of urban pollution and a possible nuclear fallout. While these developments respond to the circumstances of the time – some present at least since the penning of *Fumifugium* in 1661 – the underlying drive behind the obsession with climate control betrays a long-standing desire to mediate and harness nature itself.[16] As Eva Horn has pointed out, the pursuit of control is aimed at 'liberating human society from the contingencies of nature, and particularly of a dimension of nature that is both as elusive and ubiquitous as the air'.[17] Architectural filtering of air, as well as the establishment of cold supply chains, exploded across the globe in the second half of the twentieth century, thereby standardising the parameters of interior air and severing the interior from the threats of the exterior environment.

At its core, the development of climate control systems, including HVAC (Heating, Ventilation and Air Conditioning), in both industrial and domestic settings, was justified on the grounds of promoting health and productivity, but it inadvertently engendered a population less equipped to withstand climatic variations. As Daniel A. Barber puts it: 'Air conditioning is also people conditioning. In the "comfort zone" and other elocutions, a specific kind of human was imagined to occupy interior space in new ways.'[18] The more comfortable one becomes in the private bubble, the worse the conditions grow in the public sphere of the Earth's atmosphere. It is impossible to contravene the first law of thermodynamics: *the cost of cooling an interior comes of course at the expense of heating the exterior*.

A temporary solution as suited to the logics of Modernism, our air-conditioned and -filtered spaces allow us to ignore the unbreathable heat wave enveloping our last bastions against the coming meltdown. During the 1960s, the most extreme 'closed world' bubbles were the space missions that entailed hermetic spaceships and space suits. Ironically, in sending temporal pockets of air outside of the atmosphere, humanity realised its own home was in itself a contained bubble that cannot be endlessly exploited.

As a new environmental consciousness started to form, in the 1960s and 70s, the counterculture sought alternative ways to harness the power of air, which – like weather modelling – was originally exploited for military purposes such as Walter Bird's radar domes. The novel materiality of plastic membranes led to the birth of pneumatic structures and inflatables, which artists repurposed to create critical architectural typologies and alterative spaces. The lightweight, transformable, and seemingly invisible material allowed for the creation of collective environments that embodied universal ideals for humanity. Ant farm's *Clean Air Pod* from 1970 stands out as exemplary in form and intention. Drawing inspiration from Buckminster Fuller's utopian visions, Ant farm's collective effort manifested in a pneumatic structure designed as a safe breathing space, shielded from the fears of the external environment.[19] Other collectives, such as Utopie and Lygia Clark's students in Paris, and Haus-Rucker-Co and Coop Himmelb(l)au in Vienna, embarked on similar experiments aimed at social engagement through the use of the plastic bubble.[20] Embodying lightness and transformability, such projects epitomise the aspirations for alternative ways of coexisting on the planet, moving away from dominant notions of power and permanence. Eventually, however, the utopian bubble would pop, unable to maintain a balance between interior and exterior dynamics based on the fragility of a thin transparency.

Contemporaneous to the artistic creations of closed atmospheres, Land artists ventured out of the white cube in *plein air*. Compared to the speculative social spaces of pneumatics, their terraforming projects looked backward in time. Using as blueprints ancient geoglyphs or monuments to celestial coordinates, Land art (also referred to as earthworks) attempted to reconnect the city dweller to the 'natural' landscape. Michael Heizer followed in his father's footsteps as an archaeologist digging into the desert ground to understand deep time with *Double Negative* (1969). Robert Smithson's *Spiral Jetty* (1970) fractally reproduced the spirals of solar flares in a red lake reminiscent of the primordial seas. Nancy Holt's *Sun Tunnels* (1973–76) aligned to the solstices, while Charles Ross's *Star Axis* (1976–) and James Turrell's *Roden Crater* (1977–) are still building desert temples designed to track the stars. Like the ancient earthworks, Land art wrestles with the double dynamics of the sky: timelessness and transience; they track the enduring cosmos but also reveal the entropy on Earth. *Double Negative*'s walls are crumbling into the larger canyon, while *Spiral Jetty* was first drowned and now reveals a drought. The star-gazing projects of *Roden Crater* and *Star Axis*, which strive for the invariability of astronomy, are still not completed despite breaking ground in the 1970s. For Turrell and Ross to 'finish' their life's work, would mean surrendering their projects to entropy. Considered as a period in art history, Land art can be viewed also as studies in the second law of thermodynamics: a proof that a closed system continually proceeds to a more disorganised state.[21] Within their original conception, the

artists predicted that earthworks would appear as ruins over time, but they didn't expect them to *also* become so quickly markers of a shifting environment – from either local land use to planetary climate change.

Neither pneumatic nor entropic (inflationary nor deflationary), alternative works were created in the 1980s and 90s that engaged the landscape from an ecological framework. Since the turn of the 80s, Peter Fend has appropriated military surveillance technology of atmospheric monitoring into both his art practice and his work of political organisation and lobbying. Collaborative organisations he co-founded, such as Space Force (1979) and Ocean Earth Construction and Development Corporation (1980), are among the few artistic endeavours that engage the scale of planetary dynamics. Within the same milieu and evolving out of Land art, Agnes Denes's *Wheatfield – A Confrontation* (1982) is less concerned with moving earth then repurposing soil.[22] A process-based artwork that included planting, harvesting and distributing wheat in New York City, Denes's creation didn't require the urban art world to jump on a 4x4 to visit a remote site, but brought the rural landscape into the urban. Later, an even more ambitious work, such as *Tree Mountain – A Living Time Capsule – 11,000 Trees, 11,000 People, 400 Years* (1992–96), entailed repurposing a gravel pit into a landscaped treed park. In contrast to Land art, which waits for entropy to sculpt the work, Denes's brand of 'Land art' is born out of system thinking. It is important to note, however, that Denes's aren't 'back to the land' type of works that fetishise nature. Her projects are highly artificial – in the same way as a garden is not the wilderness. The point is not the phenomenological experience of a wheatfield or tree, but what these gestures in the landscape do to the environment. The function of the work as process is often invisible; for instance, the trees rooted in the ground are there to capture carbon in the air.[23] Denes's work – as that of her contemporary Peter Fend – is at the same time physical in its terraforming acts and invisible in its effects on atmospherics. Such practices contrast with much contemporary works that solely function within the visible realm of ecological discourse as a play of representation. The latter are not ecological in framework or function but rather take the spectacle of nature as a readymade and simply reframe it within the context of contemporary art. Phenomenologically based works such as Olafur Eliasson's *The Weather Project* (2003) and his long-running use of fog since the 1990s, or Tomás Saraceno's *Particular Matter(s)* (2022) reference outdoor atmospheric experiences and reproduce them indoors, resulting in effects akin to the history of *orangeries* and *carnivalesque* fun-houses.

Alternatively, a series of speculative architectural projects have attempted not to reference semiotically exterior climate, but to create functional microclimates. Philip Rahm's *Digestible Gulf Streams*, presented at the eleventh edition of the Venice Biennale of Architecture in 2008, combines physiological experiences with the meteorological. Echoing artist Yves Klein's and architect Werner Ruhnau's Edenic imaginations from the 1960s of air-conditioning the outdoors for an architectural climate-control of the environment, Rahm's series of projects propose a control of climate as solution to social problems.[24] Interestingly, the inhabitants of both projects are nude: the fantasy of perfectly controlled climate folds with sexual fantasy. The following edition of the Venice Biennale of Architecture included another

interior atmospheric work, *Cloudscapes* (2010) by Tetsuo Kondo Architects and the environmental engineering firm Transsolar. Rather than simply saturating a room with fog machines *qua* nightclub (*à la* Eliasson), *Cloudscapes* attempts to understand the dynamics of climate and how it interacts with architecture. For *Cloudscapes*, precise modelling of humidity, temperature and pressure zones was required so as to create a stratified climate within the space of the Arsenale. Visitors moved through three layers in the exhibition: from the clear space of the ground, through the manufactured cloud in the middle, and then above the cloud at the top of a spiral staircase. A technical feat, *Cloudscapes* inverted the shroud of Diller and Scofidio's earlier project *Blur* (2002), which created a building as a microclimate through a sophisticated network of sensors and water diffusion. Situated above a lake, the building drew water from below and diffused it as a mist around its skeletal structure in response to the dynamic fluctuations of the weather. The result was a building composed of a cloud, constantly in conversation with the lake's ecosystem. Without understanding its surroundings, the building envelope would simply not exist, revealing a naked infrastructure.

The precedent for works like *Blur* and *Cloudscapes* was the Pepsi Pavilion at Expo 70 in Osaka, Japan, in 1970. Created as a performance space for the network of artists and engineers under the banner of Experiments in Arts and Technology (E.A.T.), the interior space included a massive inflated mylar dome built by the same company that created the inflatable satellite *Echo* for the US military and space programme in 1960–64.[25] Equally impressive was the pavilion's exterior envelope shrouded in mist by the Japanese artist Fujiko Nakaya in collaboration with engineer Thomas R. Mee (whose company, founded during the production of the Osaka pavilion, would later build the fog system for *Blur*). The first of many collaborations, Nakaya went on to create an entire oeuvre of fog works, some indoors and some outdoors, most famously the permanent *Foggy Forest* (1992) at Showa Memorial Park, Tokyo, and *Fog Sculpture* #08025 (F.O.G.) (1998) at the Guggenheim, Bilbao, Spain. Fujiko's father was Ukichiro Nakaya, the inventor of the artificial snowflake in 1936. Based in Hokkaido, Japan, Ukichiro was deeply invested in understanding atmospheric conditions, which propelled him to study the natural and artificial formation of snowflakes. As he famously quipped: 'Snow crystals are the hieroglyphs sent from the sky.' During WWII Ukichiro worked for the Japanese military researching the icing of aeroplane wings, and eventually discovered that one of the key elements to the morphology of snowflake crystals was the microscopic particulate in the atmosphere. Sometimes the smallest elements produce the greatest chain effects. This took him to some of the remotest locations on Earth in search of the cleanest air, such as the peak of Mauna Loa in Hawaii, Antarctica or the floating T-3 iceberg near the North Pole.[26] While her father worked to understand how the cold created atmospheric phenomena such as the snowflake, Fukijo's fog envelope for the Osaka pavilion cooled the local air of the immediate zone surrounding the building. Originally focussed on inventing meteorological equipment, after experimenting with Fujiko in Osaka, engineer Mee went on to patent his system to control the temperature and humidity of an environment in order to protect crops.[27] Today, spraying mist into public space to cool denizens as they wait in line for traffic lights or amusement rides is a regular strategy in urban design from Japan to Dubai. Recently, Yusuke

Obuchi's experimental pavilion *Kizuki-au* at the Aichi Triennale 2022 used such mechanics as a temporary canopy and ephemeral roof to shield an interior space from sunlight. These performative strategies, including Fujiko's fog parks, are in some ways similar to solar geoengineering where mist increases the reflection of solar rays reducing the heat impact from the sun.

While Fujiko's fog envelope provided temporary relief from the heat, it became a point of contention for the surrounding pavilions. Despite first studying the site to collect baseline temperature, wind and humidity data, and then connecting the system to the control room for monitoring during the run of the exhibition, the mist still bled and obscured adjacent pavilions.[28] What Fujiko illustrated in 1970 on a microscale, the artist collective Forensic Architecture would investigate on macroscale: atmospheric politics. In their project *Cloud Studies* (2020), Forensic Architecture charts the colonisation of the atmosphere through toxic particles in the air we breathe. In the illusive blur of clouds, they locate the violent dynamics of today's political and corporate powers that disregard the impact of airborne chemicals and harmful emissions – what Rob Nixon calls 'slow violence'.[29] *Geopolitical borders are no longer boundaries*. Today it is easier to control the flow of information (e.g. 'Great Firewall of China') than the flow of particulates across state lines. Traditionally maps followed geographic topology (such as rivers and mountain ranges) as much as ethnic languages to control peoples and resources, but today they are often used to disavow responsibility. Policy's efficacy can only be enforced by the local judiciary. Smokestacks double as smoke screens. In this sense extra-judiciary artistic practices such as Forensic Architecture use a creative forum as a rhetorical space to push against the forces of established power.

Within these gestural and rhetorical realms, artistic practices can find the means to navigate the hazy intricacies of the atmosphere – simultaneously hovering within the minutiae of particles and the enormity of the planetary scale. Today's atmospheric crisis compels the need for scalability, encompassing both the micro and macro, or, more precisely, the local and the planetary. The challenge to comprehend and respond to extremes of such scale is indicative of the predicament we face, striving to attain multiple solutions for the climate crisis. Efforts aimed at reducing carbon emission have failed to meet required targets – targets that continue to move further out of reach. Even the momentary halt of the world's economic production and aviation travel due to the 2019 global pandemic did not amount to the significant reduction needed to change the course of this catastrophic trajectory. Consequently, to ensure atmospheric reparation, other controversial interventions need to be considered and tested in tandem, such as the aforementioned solar geoengineering.[30]

In *After Geoengineering*, Holly Jean Buck provides a provocative exploration into the imperatives and repercussions of geoengineering by offering a glimpse into a climate tragedy that demands technological rectification if we hope to curtail human suffering. Crucially Buck does not advocate for the immediate implementation of solar engineering; rather, she calls for careful research to address the challenges of technological precision, democratic governance and ethical considerations. Buck openly articulates: 'I'm worried that climate change will become so

severe that even more people will suffer, and that in the midst of that suffering, people will grasp for solar geoengineering without adequate caution.'[31] However, ongoing research has encountered considerable public protest, inadvertently decelerating real-world testing.[32] Sometimes the cure can be worse than the disease, but at the same time, we are past the point of 'naturally' correcting the trajectory of climate change through passivity.[33] A moralistic reaction to geoengineering driven by a romantic fantasy to return the Earth to a state before anthropogenic climate change is premised on the luxury of the local – a local still cool and sparsely populated or afforded with AC domestically and industrially. As Benjamin Bratton writes in *The Terraforming*, 'The responses to anthropogenic climate change must be equally anthropogenic.'[34] Although less than optimal – and *not* to replace the essential need to reign in consumption and waste as well as other methods of lowering temperatures – the urgency, as well as the scale, of our atmospheric issues necessitates consideration of such high-risk climate engineering measures.

Concerns regarding geoengineering perhaps stem from our history of terraforming: from the invention of agriculture with its millennia of burning vast landscapes to monumental dam constructions radically changing ecosystems and inadvertently tilting the Earth's axis. And yet even these territorial scale interventions seem controllable compared to the future release of particulates into the atmosphere. For more than one reason, solar geoengineering is compared to the birth of the nuclear age with all its potentials and problematics.[35] Nonetheless, it's vital that our historical traumas and apprehensions do not hinder the understanding of a technology that holds potential for effectively mitigating solar heat as a last resort. The process of *aeroforming* requires dedicated time and collective collaboration weighing in the risks. In the endeavour to rectify our original Promethean transgression, it becomes essential to consider both the indispensable possibilities as well as the risks of returning fire back to the sun.

While technologically a novel intervention, the release of aerosols into the atmosphere has a deep planetary history through volcanic eruptions. In fact, the entire atmosphere was originally created during the Hadean epoch when volcanoes released the water trapped in the crust of the Earth.[36] In more recent times, the localised event of a volcano spewing its ashes and other particulates into the air has redefined weather patterns. An exemplary case is the 1815 Tambora volcano eruption in Indonesia, causing a yearlong weather impact with a specifically cold summer in Europe. One of the most famous results of this climate change was the cultural production of Mary Shelley's *Frankenstein*, or *the Modern Prometheus* (1818), the first science fiction novel, which she wrote that summer while sequestered away from the outside. Just as volcanic events create undesirable weather patterns, they also demonstrate the possibility of intervening in the atmosphere to address the need for cooler temperatures. The irony that Dr Frankenstein created an uncontrollable monster roaming the Arctic – or that the sole survivor of a poisonous volcanic eruption from the same region as Tambora in M. P. Shiel's classic sci-fi novel *The Purple Cloud* (1901) was on expedition to the North Pole – is not lost upon us. But, as the risk of planetary cataclysmic shifts rises, we need to imagine possible futures before the crisis, not just reacting to events.

Rachel Carson's *Silent Spring* from 1962 is considered the seminal environmental alarm call that established the environmental movement. A marine biologist, she begins her non-fiction book with a fictional scenario titled 'A Fable for Tomorrow', where a generic location in America grows silent from anthropogenic sterilisation. Strategies of fictional writing, and specifically speculative science fiction, offer key rhetorical devices to non-fiction writers, such as Gwynne Dyer (author of *Climate Wars*, 2008) and the aforementioned Buck, for bridging real world environmental issues and future scenarios. In speculating about the future of the atmosphere, such projections continue our long-standing relation to the sky: from prophesy to weather forecasting and back to prophesy.

In regard to planetary dynamics, fictional modelling of the Earth's biosphere is also one of the only strategies available to think at full scale. In the same year as *Silent Spring*, J.G. Ballard –considered the father of 'cli-fi' or climate fiction – started his *Worlds* trilogy (*The Drowned World*, 1962, *The Burning World*, 1964 and *The Crystal World*, 1966) establishing the planetary climate disaster as a ubiquitous science-fiction genre. Yet a purely catastrophic imaginary has become as numbing as purely utopian projects. Out of the many works that followed, two series of novels in the mid-1990s directly engage climate change and its dark political issues through a lens of, ultimately, hope. Octavia E. Butler's *Parable* series (1993–98) imagines a future Californian state wrestling with climate-change-induced drought and mass unrest due to social injustice. A doctoral student of Fredric Jameson, Kim Stanley Robinson's *Mars* trilogy (1992–96) focusses on the political ramifications of climate change. In Butler's fiction, hope comes from a new religion ('Earthseed'), whereas in Robinson's world, it comes from technological solutions such as terraforming. It is interesting to note that both series in the 1990s direct their hope off world.[37] Robinson's later series, *Science in the Capital* (2004–07), firmly remains on Earth, wrestling with the conflict between science and policy, while his *The Ministry of the Future* (2020) directly addresses solar geoengineering and the potential conflicts arising from its unilateral implementation.[38] As Robinson does, it's important to acknowledge that our climate issues are not simply meteorological problems with technical solutions, but are entwined with sociopolitical and economic challenges requiring us to fundamentally see the world reimagined.[39] As always, developing new technologies is not a solution in itself; ethical governance is just as essential.

Historically, our collective imaginary evolved through three phases concerning the atmosphere. Initially, we imagined shelters from the environment, inhabiting caves and creating architecture. Subsequently, we imagined closed environments by creating hermetic bubbles –from spaceships to domestic HVAC systems. Today, we are tasked with imagining a planetary environment and engineering atmospheres. We can no longer shelter away, hiding from the sky – the consequential effects of the atmosphere are far more piercing. At this critical moment, our efforts must go beyond building higher and higher skyscrapers into the sky, and rather work collectively to rebuild the sky. The controlled and closed environments optimised for the privileged have contributed significantly to contaminating the air and threatening much life on the planet. To face the unpredictable climate patterns of our near futures, we must consider shaping the atmosphere.

1 A previous volume titled *BREATHLESS* collected a variety of concerns regarding the accelerated concerns of our atmosphere, including forest fires, racial tensions, Covid-19, pollution, etc. See Ala Roushan, *BREATHLESS*, Toronto: Power Plant, 2021.

2 Solar geoengineering includes stratospheric aerosol scattering into the upper atmosphere as well as other interventions such as marine cloud brightening above the oceanic surface. See Harvard's Solar Geoengineering Research Program, available at: https://geoengineering.environment.harvard.edu/geo-engineering (last accessed on 18 September 2023)

3 John Durham Peters, *The Marvelous Clouds: Toward a Philosophy of Elemental Media*, Chicago: University of Chicago Press, 2016, p.170.

4 Ira Spar, 'Mesopotamian Creation Myths', Department of Ancient Near Eastern Art, Metropolitan Museum of Art, April 2009, available at: https://www.metmuseum.org/toah/hd/epic/hd_epic.htm (last accessed on 18 September 2023)

5 See exhibition title card for *Book of the Dead*, section 161, *For breaking an opening in the sky*, Metropolitan Museum of Art, June 2021: 'this spell granted that the deceased Imhotep will have air, essential for life, to breathe. There is no text version of the spell here, only two versions of the vignette–one here and the other at the end of the papyrus–that show figures of the ibis-headed Thoth holding up the pillars that support the sky.'

6 See Dehlia Hannah's essay 'Cosmic', which further divides meteorological versus astronomy according to the differing conceptions of time: *kairos* versus *chronos* (respectively). In Charles Stankievech, *The Desert Turned to Glass* (ed. A. Roushan, D. Hannah and Nadim Samman), Berlin: Hatje Cantz, 2023.

7 Lorraine Daston, 'The Empire of Observation, 1600–1800', in *Histories of Scientific Observation* (ed. Elizabeth Lunbeck and L. Daston), Chicago: University of Chicago Press, 2011, p.87

8 See Paul N. Edwards. *The Closed World: Computers and the Politics of Disclosure in Cold War America*, Cambridge, MA: MIT, 1996 and *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming*, Cambridge, MA: MIT, 2010.

9 In a further referential play on the meteorological, one of the most notorious counter-cultural movements during the Cold War was the US domestic resistance group called The Weather Underground.

10 Stankievech was deployed by the Canadian Department of Defence's History Directorate at CFS ALERT in 2011 to document its history of signals intelligence (SIGINT) within his long-term research project on the DEW Line (Distant Early Warning) while living in the Arctic from 2007 to 2012.

11 Stankievech first used the term 'Warm War' in 2009 to describe conflicts arising from global warming. See C. Stankievech, 'Cinema, Gramophone, Radio: A Quiet History', *eContact!*, vol.11, no.2, 2009.

12 No amount of irony can be lost on the rarely mentioned fact that the US military creates a vast carbon footprint, and like all militaries, is exempted from COP emission cuts. For example, an F-35 jet emits 2.2 tonnes of CO2 in an *hour* compared to the 4.17 tonnes emitted by a typical passenger car over an entire *year*. This comparison was made in the lecture 'A Crisis of Culture: Art, Literature, and the Humanities in the Antrophocene' by Amitav Ghosh at the University of Toronto, 9 October 2019.

13 *Bunker Archéologie* (1975) was both an exhibition of photographs at the Museum of Decorative Arts in Paris and a philosophical treatise. Paul Virilio, *Bunker Archeology* (trans. George Collins), New York: Princeton Architectural Press, 1994, p.37.

14 Peter Sloterdijk, *Terror from the Air* (trans. Amy Patton and Steve Corcoran), Los Angeles: Semiotext(e), 2002, p.14.

15 See Sloterdijk's trilogy *Spheres* (1998–2004) for a comprehensive political-philosophical treatise on the spatial relation between inside and outside.

16 John Evelyn's *Fumifugium* (1661) is considered the first major work on air pollution, outlining a history of pollution in London since medieval times, as well as solutions such as removing polluting industries from the city using vegetation as a remedy. Available at: https://archive.org/details/fumifugium00eveluoft/page/n3/mode/2up (last accessed on 18 September 2023)

17 Eva Horn, 'Air Conditioning: Taming the Climate as a Dream of Civilization', in *Climates: Architecture and the Planetary Imaginary* (ed. James Graham and Caitlin Blanchfield), New York: Columbia Books on Architecture and the City, 2016, pp.232–41.

18 Daniel A. Barber, *Modern Architecture and Climate: Design before Air Conditioning*, Princeton: Princeton University Press, 2020, p.262

19 See Lydia Kallipoliti, *Architecture of Closed Worlds*, Zürich: Lars Müller, 2018 for a discussion of Ant Farm's Clean Air Pod in relation to Francois Dallagret's design 'The Environment-Bubble' for Reyner Banham's text 'A Home Is Not a House' (1965).

20 Marc Dessauce, *The Inflatable Moment: Pneumatics and Protest in '68*, New York: Princeton Architectural Press, 1999.

21 An interesting parallel could be made between Paul Virilio's photographs of partially buried WWII bunkers and Smithson's *Partially Buried Woodshed* (1970). Following the Jena Romantics, Albert Speer designed Nazi architecture

with the concept of *Ruinenwert* or 'Ruin value'.

22 See Agnes Denes, 'Wheatfield–a Confrontation (1982)', in *Absolutes and Intermediates* (ed. Emma Enderby), NYC: The Shed, 2019, pp.256–57.

23 See her most recent proposal for a New York City forest park: A. Denes, 'Model for A Forest for New York (2019)', in *Absolutes and Intermediates*, *op. cit.*, p.4.

24 For a collection of writing and projects see Yves Klein, *Air Architecture* (ed. Peter Noever and François Perrin), Ostfildern-Ruit: Hatje Cantz, 2004.

25 W. Patrick McCray, 'When Artists, Engineers, And Pepsico Collaborated, Then Clashed At The 1970 World's Fair', Spectrum IEEE, March 2020, available at: https://spectrum.ieee.org/when-artists-engineers-and-pepsi-co-collaborated-then-clashed-at-the-1970-worlds-fair (last accessed on 18 September 2023)

26 Ukichiro Nakaya, 黒い月の世界 (The World of the Black Moon), *Bungei Shunjū*, August 1957, available at: https://www.aozora.gr.jp/cards/001569/files/56726_56781.html (last accessed on 18 September 2023).

27 Thomas R. Mee, Environmental control method and apparatus, US Patent # US4039144A, 1973.

28 For site studies, see Jimmy Stamp, 'When PepsiCola Allowed a Team of Artists to Wreak Creative Havoc', *Smithsonian Magazine*, 26 September 2013, available at: https://www.smithsonianmag.com/arts-culture/when-pepsicola-allowed-a-team-of-artists-to-wreak-creative-havoc-109661/ (last accessed on 18 September 2023). For monitoring during the exhibition, see Cyrille-Paul Betrand, 'The Pepsi-Cola Pavilion, Osaka World's Fair, 1970', in *Virtuelle und ideale Welten* [online], Karlsruhe: KIT Scientific Publishing, 2012, pp.185–97.

29 See Rob Nixon, *Slow Violence and the Environmentalism of the Poor*, Cambridge, MA: Harvard University Press, 2011.

30 In addition to the reduction of carbon outputs and shifting to 'greener' energy, other experimental interventions (which all have their pros and cons) include carbon capture, wrapping glaciers, extracting warm sea water seeping under Antarctica, building artificial islands, kelp farming, cloud seeding, and hopefully newer bolder ideas.

31 Holly Jean Buck, *After Geoengineering: Climate Tragedy, Repair and Restoration*, London: Verso, p.242.

32 In 2021, the Keutsch Group at Harvard had to cancel their first SCoPEx test due to protests and community push back by environmental activists and Indigenous groups.

33 In opposition to this perspective, see the pessimistic critique of rational-optimists: Andreas Malm. 'The Future Is the Termination Shock: On the Antinomies and Psychopathologies of Geoengineering. Part Two', *Historical Materialism*, vol.31, no.1, 2023, pp.3–61.

34 Benjamin Bratton, *The Terraforming* [ebook], Moscow: Strelka, 2019.

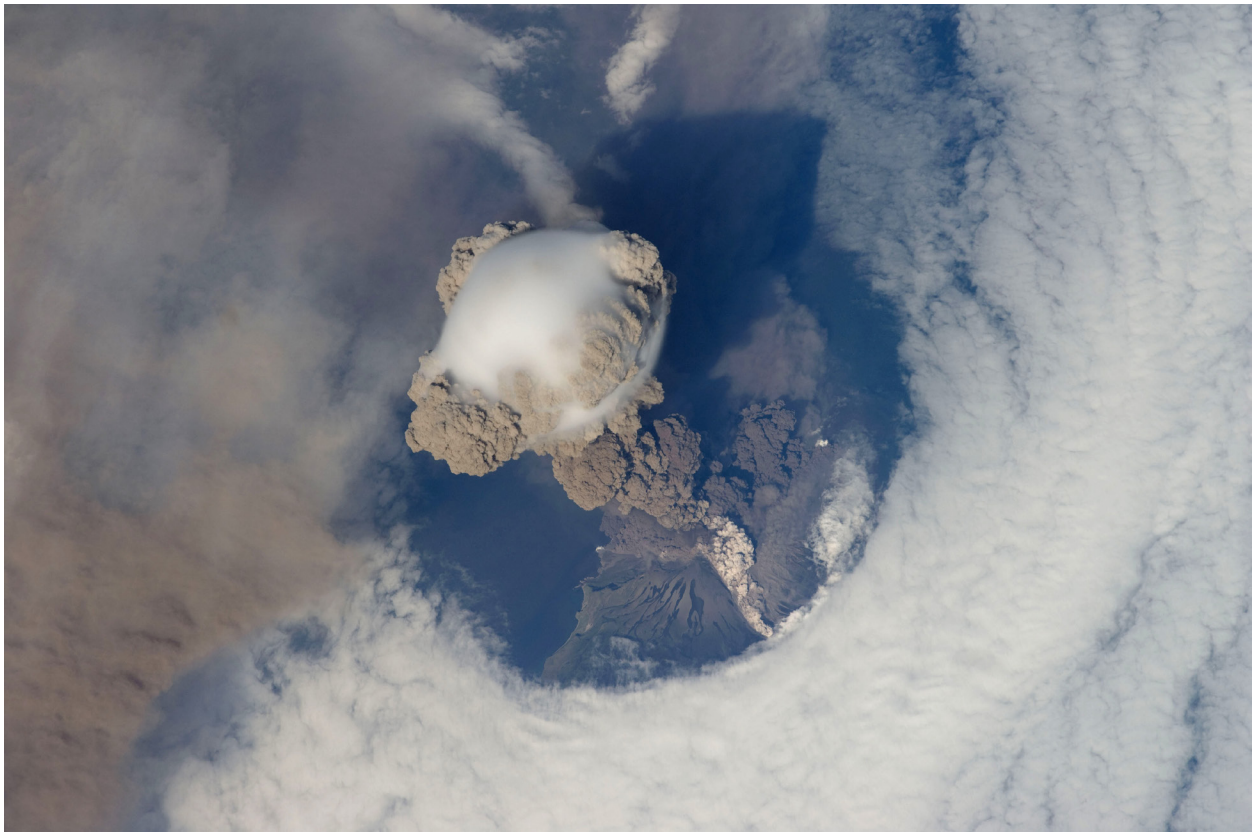
35 Suggested parallels include, defining the Anthropocene based on radioactive isotopes released by the nuclear explosions into the atmosphere, the original fear of an uncontrollable chain reaction resulting in the Earth's atmosphere catching fire, unilateral testing exploiting locals, the need for an international committee to navigate politics, etc.

36 James F. Kasting, 'Early Earth Atmosphere and Oceans' in *Earth's Oldest Rocks* (ed. Martin J. Van Kranendonk, Vickie C. Bennett and J. Elis Hoffmann), Amsterdam: Elsevier: 2019, p.50.

37 It would be remiss not to mention Frank Herbert's genre-transcending novel *Dune* for its ground-breaking creation of a comprehensive planet's ecology and eventual terraforming. F. Herbert, 'Appendix I: The Ecology of Dune', *Dune*, Boston: Chilton, 1965.

38 Anthologised and updated as Kim Stanley Robinson, *Green Earth*, New York: HarperCollins, 2015.

39 T.J. Demos's 2018 polemic against geoengineering equates the Anthropocene with the neoliberal and thus for him is completely incompatible with social justice – a tenuously tethered logic. However, many calls for geoengineering today are premised on the need for the implementation driven by social justice as this article points out. Demos criticises the government for not pre-emptively investing in infrastructure to mitigate the climate disaster of Hurricane Katrina, but responsible and democratic experiments in solar geoengineering could be *part* of such investments. See T.J. Demos, 'To Save a World. Geoengineering, Conflictual Futurisms, and the Unthinkable', *E-flux journal*, no.94, October 2018, available at: https://www.e-flux.com/journal/94/221148/to-save-a-world-geoengineering-conflictual-futurisms-and-the-unthinkable/ (last accessed on 18 September 2023).



Top:
NASA, Sarychev Peak Eruption, Kuril Islands, Japan. 2009. #ISS020-E-9048.

Bottom:
Book of Dead.
Photograph: Charles Stankievech

Left:
Transolar and Tetsuo Kondo Architects, *Cloudscapes*, 2010. Installation view, International Architecture Exhibition, La Biennale di Venezia, 29 August–21 November 2010. Courtesy of Tetsuo Kondo Architects

Right:
Fujiko Nakaya, *Foggy Forest*, 1992, Showa Memorial Park. Photograph: Ala Roushan

CONTEXTS

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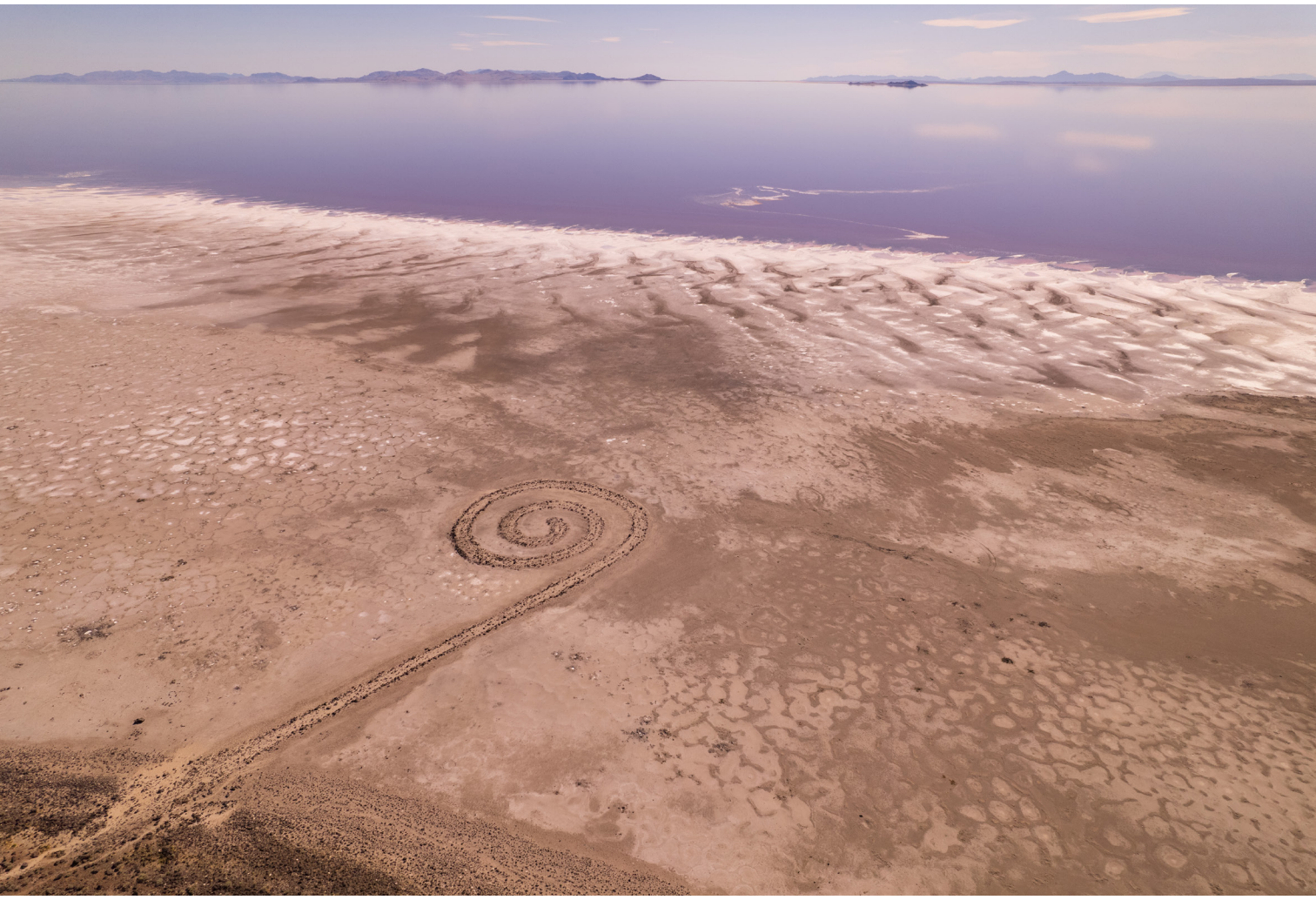

AFTERALL