On Weather Forecasting

Infrastructure, Models, and Material Registration

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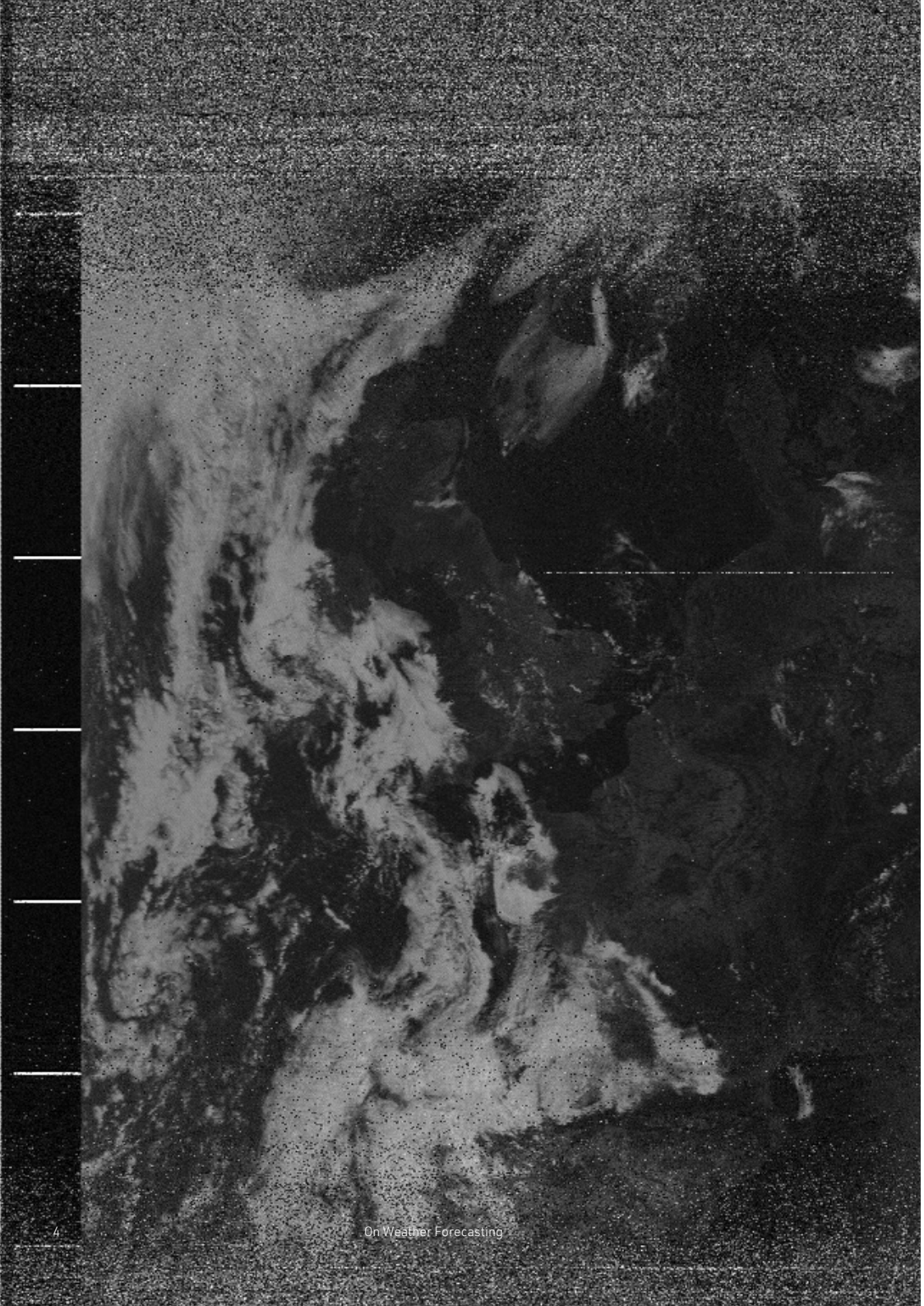
Introduction

The emergence of modern weather forecasting marks the expansion of an infrastructural apparatus that renders environmental media calculable, governable, and tradable. The forecast is a technical, social, political, and economic construction: an assemblage of instruments, institutions, models, and interests that is never reducible to the atmosphere it claims to represent. Since its formation, capital and empire have arranged themselves to capture and entrench access to this apparatus. The result is an atmosphere of information asymmetry that grants tremendous power to make the world to those who hold it.

This essay examines the contemporary moment of that history: the shift from a publicly administered forecasting infrastructure to a privatized one, and the phenomena of that shift. The central argument is that the privatized forecast functions as a device of temporal capture. By converting publicly produced atmospheric knowledge into excludable proprietary information, financial capitalism generates an asymmetry between what private actors know about the atmospheric future and what public institutions and ordinary people can access. This asymmetry is not incidental to the apparatus but constitutive of its value.

The analysis draws on the critical theory of the apparatus, the political economy of financial capitalism, and the history of meteorological institutions. It also draws on a body of artistic practice, presented throughout alongside the argument, that attempts to reveal and inhabit the peripheral conditions of the forecasting apparatus. Art is treated here as an alternative mode of modeling: a practice that produces situated, partial, and relational knowledge against the forecast's claim to a view from nowhere.

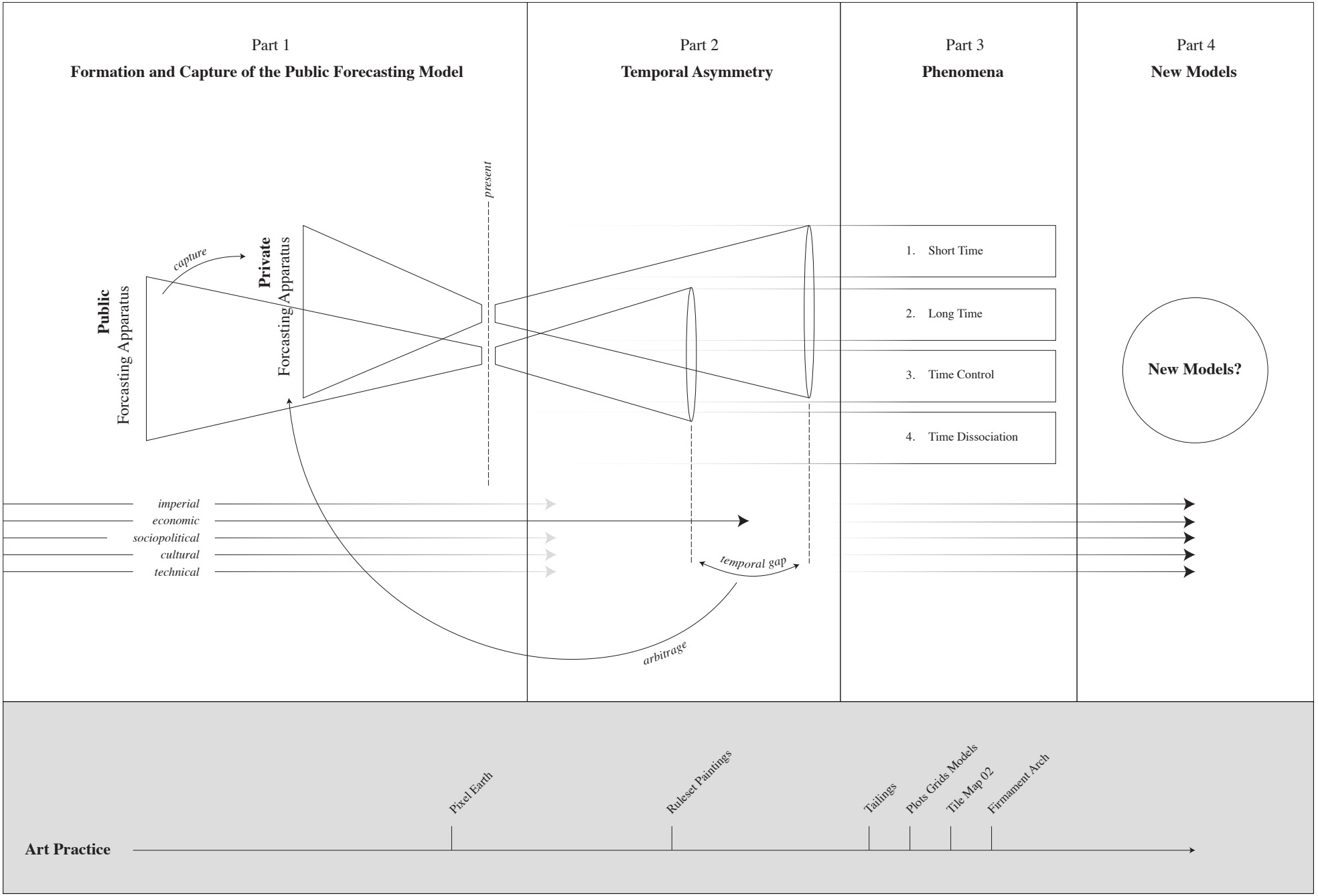
The essay proceeds in four parts, tracing the historical formation of the public forecast, the economic logic driving its privatization, the phenomena the privatized apparatus produces across four temporal registers, and a concluding turn toward alternative practices and models. If the essay has a proposal, it is that a plurality of ways of relating to atmospheric and temporal uncertainty is both possible and necessary, and that how we build our models is coproductive with the world they produce.



Structure

The following diagram describes the structure of this project and its fundemental conceptual framework.

The first section traces the historical formation and dissolution of the public forecast model in the United States, situating the forecast as a device whose composition has always been shaped by intersecting economic, political, and technical forces. The second section introduces the economic logic underwriting the contemporary shift toward privatization, arguing that financial capitalism attaches to the forecast as an engine of temporal asymmetry. The third section traces the phenomena this apparatus produces across four temporal registers: short-time financial extraction, long-time capital withdrawal from vulnerable geographies, technical proposals for atmospheric intervention, and the subjective dissociation of the human from embodied atmospheric experience. The conclusion turns toward situated alternatives, considering the almanac, artistic practice, and the relational structures of financial capitalism itself as grounds for a plurality of ways of relating to atmospheric and temporal uncertainty.


Part 1
Formation and Capture of the Public Forecasting Model
Part 2
Temporal Asymmetry
Part 3
Phenomena
Part 4
New Models
Public
Forcasting Apparatus
Private
Forcasting Apparatus
capture
present
1. Short Time
2. Long Time
3. Time Control
4. Time Dissociation
New Models?
imperial
economic
sociopolitical
cultural
technical
temporal gap
arbitrage
Art Practice
Pixel Earth
Ruleset Paintings
Tailings
Plots Grids Models
Tile Map 02
Firmament Arch

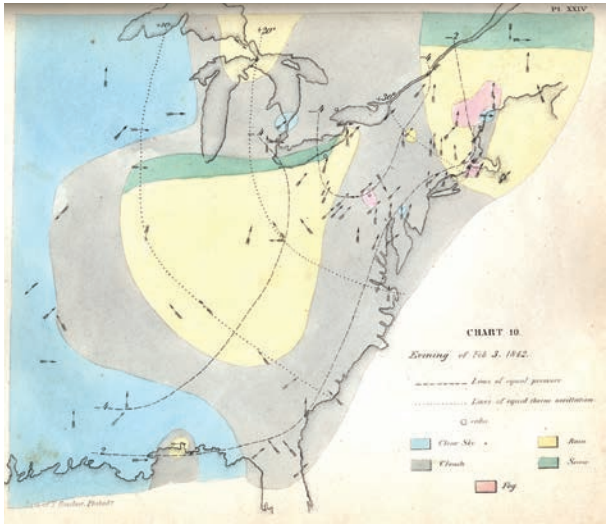
Part 1

The Formation and Capture of the Public Forecast Model

This section discusses the layers that compose the forecasting apparatus: from the sensing instruments that make observations of atmosphere and ground, to the model layer that aggregates and forms an interpretive mediation of those observations, to the distributional layer that applies the forecast to ground. The section traces the evolution of these layers from the early days of the United States Signal Service through to today's AI forecasting models owned and operated by large tech corporations.

This shift is described through a flow of imperial, technical, economic, and sociopolitical forces that shaped the weather forecast's emergence in the 1800s and continue to drive its evolution today. These flows determine how the forecast is used, as well as what it includes and excludes from its temporal gaze.

Critically, these forces also determine who controls the forecasting apparatus, and subsequently its composition and orientation. Control of this assemblage of instruments, institutions, interpretive layers, and routes of dissemination ultimately decides who has access to the information it produces, and who does not.



[Figure 1] Early weather forecast produced by the US Signal Service.

[Figure 2] TIROS program weather satellite, 1970. The TIROS Program (Television Infrared Observation Satellite) was NASA's first experimental step to determine if satellites could be useful in the study of the Earth. At that time, the effectiveness of satellite observations was still unproven. Since satellites were a new technology, the TIROS Program also tested various design issues for spacecraft: instruments, data and operational parameters.

NASA. "TIROS: Television Infrared Observation Satellite Program." NASA Science. Last modified August 17, 2023. science.nasa.gov/mission/tiros/

Formation of the 'Public' Model

The fragile popular narrative at the end of the 20th century was that the US weather forecast was a public good, produced by the State due to its exclusive technical capacity to build such a sensing infrastructure. The state institutions emblematic of this idealized role of the forecast, NASA, the National Weather Service (NWS), and the National Oceanic and Atmospheric Administration (NOAA), positioned themselves as producers of democratically governed scientific objectivity, producing and disseminating services for the good of the global public. In the reorganization plan that created NOAA in 1970, the agency was framed as serving a national need for "better protection of life and property from natural hazards...for a better understanding of the total environment." [1]

Of course, the missions of NOAA and these institutions were aspirational myths at best, and transparently admit an allegiance to property, which is inherently private and inequitably distributed. The dual allegiance to life and property is telling of the schizophrenic nature of these institutions, instruments, and programs. The US public model was also largely public only for those aligned with the national interest. Internationally, it advanced US hegemony while presenting as open for the common good. Examples of this tension, between data that was on one hand open and accessible while also furthering the US position, are prolific, if subtle. The capture of valuable geostationary orbital positions [2], the establishment of American meteorological standards as the global default [3], and the embedding of US technological and commercial interests in the architecture of planetary atmospheric governance serve as examples. [4]

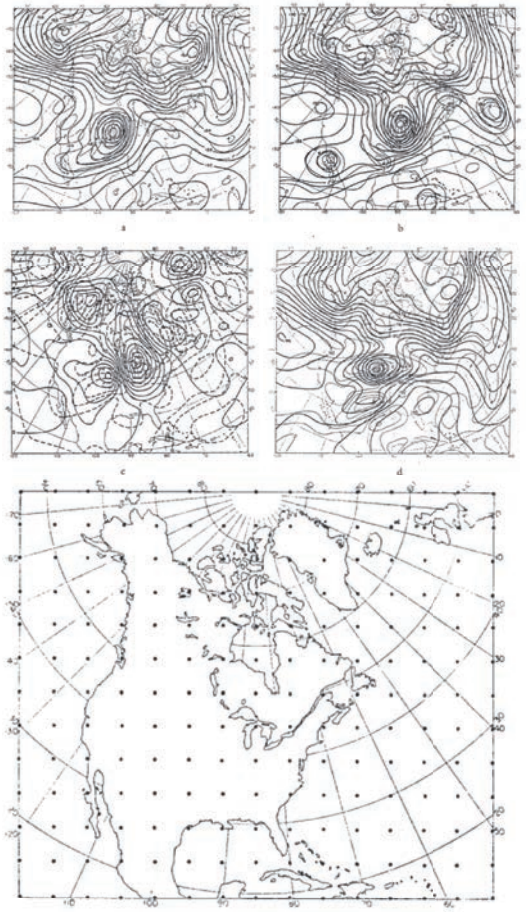
What is definitely less subtle is the entangled legacy of the weather forecast with the US military. [Figure 1] This mutual history is well documented and clear from the founding of the nation's first weather reports and forecasts. The US Signal Service, established in 1870 under the Army Signal Corps, built the observational network that made national weather forecasting possible on the same military telegraph infrastructure it had constructed during the Civil War. [5] NOAA and the NWS inherited both the infrastructure and the institutional logic of the military apparatus that preceded them.

The forecast was a device used for the State's westward expansion and its project of dispossession and murder of indigenous people of North America. [6] The D-Day invasion of Europe was predicated on the Allies' superior forecasting models over Germany's. [7] In the post-war period, as the hard power of military necessity moved to the soft power of industry, the forecast moved with it: reoriented as a tool to enable the extractive practices of economic and political power, with the State gradually offloading this role to the instruments of global capitalism. Still, in 2025, the US Federal Government has explicitly claimed that its NWS performs "intelligence, counterintelligence, investigative, or national security work," providing "weather and climate data that inform the weather forecasting used to plan U.S. military deployments." [8]

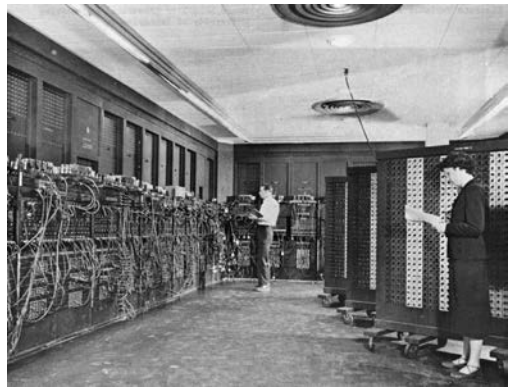
The iterative arrangement of the forecasting apparatus from its origins as the US Signal Service through to today's forecasting infrastructure shows a device fundamentally torn between a cultural and legal understanding of the sky and weather as a kind of commons, and a device that produces information about a common future that can be exploited and weaponized by those with access in the present.

The social and legal framework that gave the public model its legitimacy drew on a longer tradition of atmospheric commons. Legal precedent extending from maritime law, which had governed international waters as shared space, extended implicitly in culture and explicitly in law to the domain of the atmosphere, providing a basic orientation to operate in it, to benefit from what it yields, and that its access should be governed collectively. This principle was codified through the World Meteorological Organization's international data-sharing agreements, which treated the global observational network as a collective resource whose outputs no single state or commercial entity could claim. [9] A state monopoly on the technical ability to build sensing and modeling infrastructure reinforced this arrangement from below. As long as only state actors could assemble and operate the necessary infrastructure, the question of private ownership of the forecast did not arise with force.

Understanding the contradictions of the US forecasting apparatus and the myths of its institutions as neutral observers of the weather, we can acknowledge that in economic terms it is largely categorizable as a public good: non-excludable, open to being received by all, and non-rivalrous, where one person knowing the forecast does not diminish anyone else's access to it.



[Figure 3] The first numerical weather forecast was computed in 1950 by a team led by meteorologist Jule Charney and mathematician John von Neumann, using the ENIAC at the Institute for Advanced Study in Princeton. The project was funded by the Office of Naval Research and the Air Force Cambridge Research Laboratories. The forecast was a retroactive 24-hour prediction of a historical weather event, run as proof of concept. The machine required an entire building to operate and took 24 hours of computation to produce a forecast covering 24 hours of atmospheric time.



[Figure 4] Glen Beck and Betty Snyder programming the ENIAC at the Ballistic Research Laboratory, Building 328, Aberdeen Proving Ground, Maryland, c. 1947. Photograph by the United States Army. Public domain. Wikimedia Commons.

These non-rival and non-excludable qualities were only a condition of the economic and technical constraints that made the early and modern forecast possible. The ability to create the most precise temporal models of weather had, for the length of the forecast's history, been held by the State.

The first numerical weather forecast was run in 1950 on the ENIAC at the Institute for Advanced Study in Princeton, funded by the Office of Naval Research and the Air Force Cambridge Research Laboratories. [Figure 1] The machine occupied an entire building and cost millions of dollars to operate. No private entity had access to comparable computational infrastructure. The forecast was public because the means of producing it were exclusively state property.

The satellite era reproduced the same condition at greater scale. TIROS-1, launched in 1960, and the GOES program that followed required the concentrated investment of the State (see section: Pixel Earth). Private actors had no launch capability or orbital presence, and no means of assembling or operating the sensing layer. The forecast remained a public good because the technical barriers to private entry were, for a specific period of history, insurmountable.

Running beneath the State's technical monopoly, however, was a persistent desire to privatize aspects of the forecasting apparatus. Profit-seeking entities increasingly understood that those who could control access to the forecast would sell superior predictive capacity: which is to say, they would sell a mechanism for arbitrage. The State's technical monopoly, combined with the economic means of sensing and modeling weather, were the structural conditions that held the public model in place.

This arrangement had a specific economic genealogy. The telegraph's democratization of weather information in the 1840s and 1870s established forecasting as a public good precisely because private provision was recognized as inequitable and insufficient. The fundamental question, as Erik Craft's economic history of the forecast documents, was whether "private producers of weather information could create a system whereby they earned enough money from users to cover the costs of creating the information." [10] It was answered in the negative. Forecasting became a state service because the alternative was lethal inequality at the hands of the weather. [11]

Incrementally, the technical and distributional infrastructure of the forecast

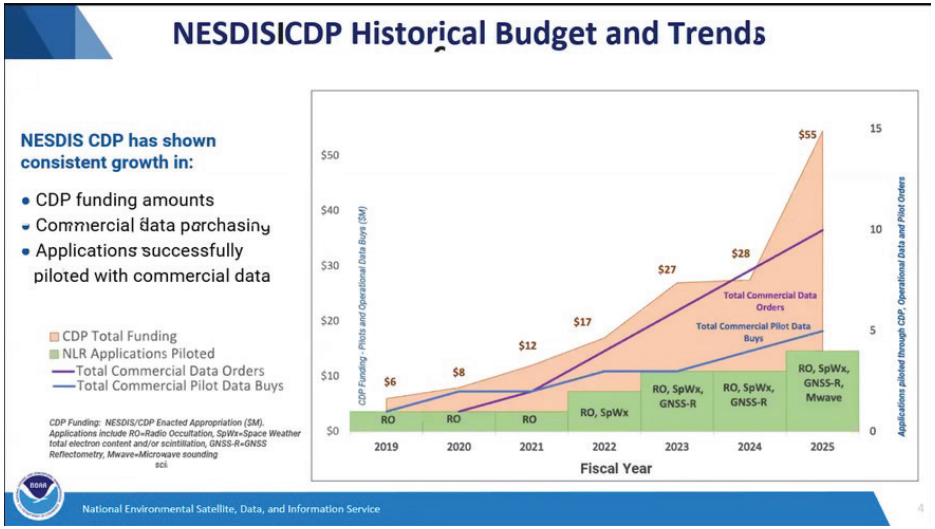
was portioned off as commercial services run by private corporations. The Weather Channel launched in 1982 and the Reagan administration simultaneously proposed privatizing NOAA's satellite operations entirely. [12] AccuWeather began selling premium commercial forecasts at scale in 1988. By the 1990s, the rise of energy weather trading had consolidated the model that has scaled into the present: a public infrastructure producing open and freely available data, and a private industry that sells the intelligence derived from it.

Capture, and the Private Earth Systems Model

The forecasting apparatus operates across three distinct layers: a sensing layer of satellite and observational infrastructure that gathers atmospheric data; a model layer that processes that data into interpretive forecast knowledge; and a distributional layer that pushes forecast products to the ground through warnings, services, and commercial applications. Each layer operates under a different regime of ownership, access, and control.

At the height of the state's public model, each layer was predominantly publicly owned and operated. The sensing layer, consisting of NOAA's GOES constellation, COSMIC-2 radio occultation network, ground weather stations, ocean buoys, and more, provided continuous planetary atmospheric coverage, largely freely transmitted. The National Weather Service's numerical prediction system served as the model layer, an interpretive repository of weather truth processed on federal computing infrastructure. The same agency's warnings and forecast products were served to the public as a basic distribution layer, with commercial weather services and proprietary forecasts operating downstream as augmentation rather than replacement. The apparatus was largely owned, operated, and accessible by the public at each layer.

The capture of the sensing layer has proceeded through a systematic shift to a framework of "Data as a Service," where data is not collected and disseminated by the state but procured through outside providers. [Figure 5] The Weather Research and Forecasting Innovation Act of 2017 was the legislative instrument that required NOAA to procure commercial satellite data and prioritize public-private partnerships over public infrastructure. Congress and successive administrations have since directed federal agencies to "purchase and use US commercial space capabilities and services to the maximum extent practical."

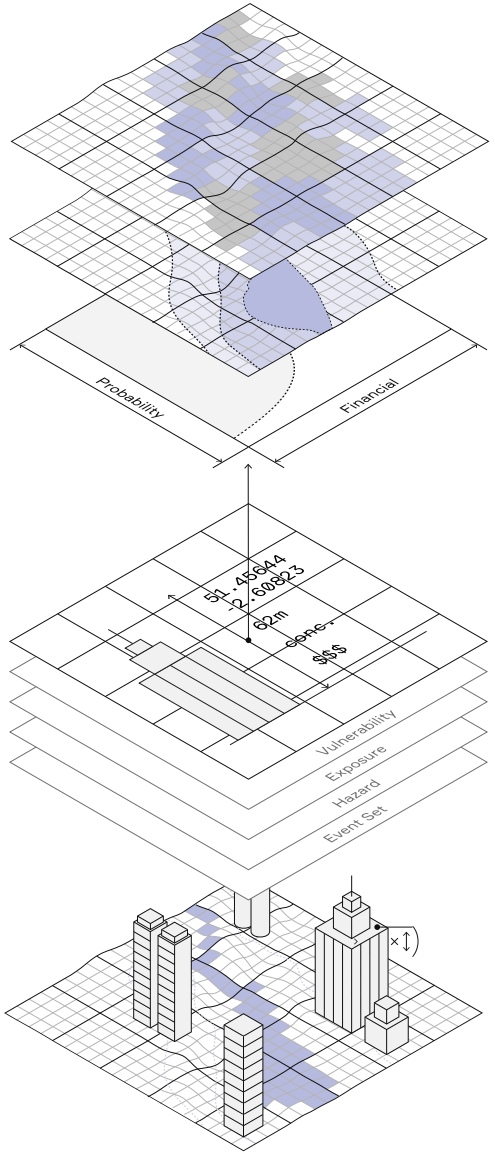


[Figure 5] NOAA's commercial data program budget grew dramatically from 2019 to 2025, with its budget increasing from $6 million to $55 million during that time.

Image Credit: National Environmental Satellite, Data, and Information Service

[13] The Commerce Department has committed to purchasing "billions of dollars over ten years" of commercial weather data. [14] NOAA's COSMIC-2 satellite constellation, which provided the global atmospheric profiles critical to forecast accuracy, is being decommissioned and replaced with commercially purchased data.

The capture of the forecasting apparatus is also now possible from inside the model layer. AI-based forecasting models developed by Google DeepMind [Figure 10], Huawei, Microsoft, and Nvidia are trained on the historical observational record assembled by NOAA and its international partners across the preceding century. At medium-range timescales they achieve forecast skill competitive with, or superior to, public physics-based models. The compute infrastructure they require, hyperscale data centers and purpose-built AI accelerators, is held entirely by non-state actors. This creates the conditions for a second direction of capture: if private models are demonstrably competitive with public ones, the technical case for public model investment collapses. The



[Figure 8] Representation of the application layer of the forecast stack, which has largely been the domain of private industry since the 1980s.

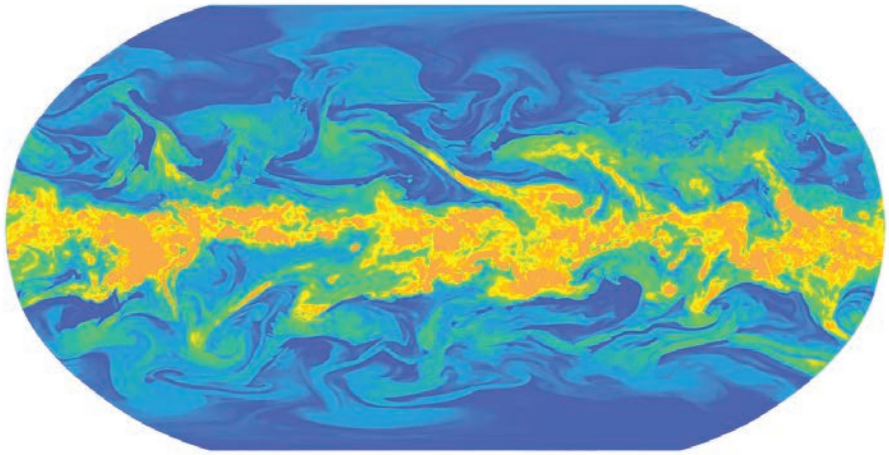
defunding of NOAA removes the competition and makes the argument for privatization simultaneously.

In February 2025, 880 NOAA employees were terminated in a single day. By June, the National Weather Service Environmental Modeling Center had discontinued four operational forecast models. The proposed 2026 federal budget eliminates all funding for NOAA's climate, weather, and ocean research laboratories. The National Centers for Environmental Information retired the Billion Dollar Weather and Climate Disasters database, a continuous public record of accumulating climate damage costs, discontinued without replacement. The Office of Oceanic and Atmospheric Research, including the Geophysical Fluid Dynamics Laboratory, will be cut by 74%. What is being removed is public interpretive capacity: the researchers, modelers, and scientists who translate atmospheric data into publicly legible knowledge. [15]

The distributional layer remains nominally public, maintaining the appearance of a public forecast service. But as the sensing and model layers become increasingly privatized, what reaches the ground through public channels is an increasingly impoverished service. The gap between the proprietary forecast and publicly available knowledge is the space where value can be extracted through asymmetric information about the future. This is space for industry to exploit market failures across short and long forecast environments. For capital, this gap is generative terrain.

[Figure 9] SpaceX's Transporter ride-share program launches satellites for commercial and government clients, including private weather companies such as Tomorrow.io and Spire Global, whose atmospheric sensing satellites feed directly into commercial weather forecasting networks.

Image Credit: SpaceX webcast



[Figure 10] Google Deepmind AI based Earth Systems Model
Image Credit: Google DeepMind. "WeatherNext 2: Our Most Advanced Weather Forecasting Model."

Footnotes

[1] Nixon, Richard. Reorganization Plan No. 4 of 1970. July 9, 1970. Reproduced at NOAA Office of General Counsel, noaa.gov/noaa-legal-history.

[2] The most valuable geostationary orbital positions under ITU treaty arrangements systematically favored early-moving spacefaring nations. The equatorial arc that the NOAA GOES weather satellites occupy was not negotiated with the equatorial nations beneath it and therefore built a structural dependence on US-provided intelligence about their own atmospheres. Collis, Christy. "The Geostationary Orbit: A Critical Legal Geography of Space's Most Valuable Real Estate." The Sociological Review 57, no. S1 (2009): 47–65.

[3] The WMO's open data sharing framework, which the US championed as a founding principle of international meteorological cooperation, extended this asymmetry rather than correcting it. Equal access to raw observational data is not equal access to the forecast when the capacity to process that data is unevenly distributed. The US had analytical and computational advantage over any other nation, which meant that the same collective data stream produced better intelligence in American hands than anywhere else. The framework the US promoted was designed around conditions in which the US could and would compete. Miller, Clark. "Climate Science and the Making of a Global Political Order." In Earthly Politics: Local and Global in Environmental Governance, edited by Sheila Jasanoff and Marybeth Long Martello. MIT Press, 2004.

[4] This tension is held in many other such programs outside of weather, such as the U.S. Landsat program, a joint venture of NASA and the U.S. Department of the Interior, which provided a planetary view of the earth and its natural resources and was systematically used by the US and private industry for mineral extraction projects across the globe. The proliferation of satellite images of mineral-rich terrains, and the national buy-in facilitated by the USAID program, bolstered the extractive operations for the world's largest companies, while simultaneously empowering the environmental conservation efforts in those same extractive regions. Black, Megan. The Global Interior: Mineral Frontiers and American Power. Cambridge, MA: Harvard University Press, 2018.

[5] Fleming, James Rodger. Meteorology in America, 1800–1870. Baltimore: Johns Hopkins University Press, 1990.

[6] Raines, Rebecca Robbins. Getting the Message Through: A Branch History of the US Army Signal Corps. Washington: Center of Military History, 1996.

[7] Stagg, J.M. Forecast for Overlord. London: Ian Allen, 1971.

[8] Executive Order on Exclusions from Federal Labor-Management Relations Programs, February 2025.

[9] World Meteorological Organization. Resolution 40 (Cg-XII): WMO Policy and Practice for the Exchange of Meteorological and Related Data and Products. Twelfth World Meteorological Congress, Geneva, 1995. community.wmo.int/en/resolution-40

[10] Craft, Erik. "An Economic History of Weather Forecasting." EH.Net Encyclopedia, edited by Robert Whaples. October 6, 2001. eh.net/encyclopedia/an-economic-history-of-weather-forecasting/

[11] Craft, Erik. "Private Weather Organizations and the Founding of the United States Weather Bureau." Journal of Economic History 59, no. 4 (1999): 1063–1071.

[12] citation needed — Reagan administration NOAA privatization proposal, 1983.

[13] Congressional Research Service. "NOAA's Commercial Data Program: Background and Considerations for Congress." IF12671. Washington, DC: Congress.gov, May 2024. congress.gov/crs-product/IF12671

[14] Foust, Jeff. "NOAA Seeks More Money and Flexibility for Commercial Weather Data Program." SpaceNews, January 28, 2026. spacenews.com/noaa-seeks-more-money-and-flexibility-for-commercial-weather-data-program/

[15]https://www.propublica.org/article/trump-noaa-budget-cuts-climate-change-modeling-princeton-gfdl

Pixel Earth

Pixel Earth is a directional linkage to NOAA's GOES-16 satellite, a weather satellite in geostationary orbit above the equatorial center of Earth's Atlantic Ocean. The geosynchronous position of this satellite provides a fixed point in the sky for our installation to point and for a constant, reliable connection to a piece of human sensing infrastructure surrounding the planet. From a stream of radio noise, our installation downloads and projects a continuous stream of images of earth. Among the numerous images received from the satellite are RGB images of the earth in visible light.

These images, a half earth, have become ubiquitous since the 1960s, when the first Earthrise was released. Today these same types of images hold a twist of this same sublime beauty, but are instead as much about the extensive sensing infrastructure that enables their capture.

The pixel is the base unit of this infrastructure. A single pixel from a high-resolution GOES image corresponds to a square kilometer of Earth's surface. Pixel Earth projects that pixel onto a corresponding square meter of ground, producing a scaled model of the data that forms our collective knowledge of planetary weather and climate systems. Information that ordinarily moves through institutional channels, processed and abstracted long before it reaches a screen, is brought into direct contact with the physical landscape it represents.

GOES-16 belongs to a specific era of the forecasting apparatus: the public era. It was built with federal funding, operated by NOAA, and designed to make atmospheric data freely available. The pixel it transmits is a product of that arrangement, a form of planetary knowledge held, at least in principle, in common. That arrangement is now being dismantled. The sensing infrastructure surrounding the earth increasingly includes privately owned satellites, proprietary data streams, and commercial platforms that make the same atmospheric intelligence available to paying clients before it reaches public systems or the communities most exposed to what those systems measure.

Of course geostationary orbit is not neutral space. The equatorial arc that GOES-16 occupies is finite, governed by international treaty, and historically contested along lines that track the same imperial and economic forces shaping the forecasting apparatus on the ground. The nations that secured orbital positions in this area of space, the wavelengths they chose to monitor, and the data

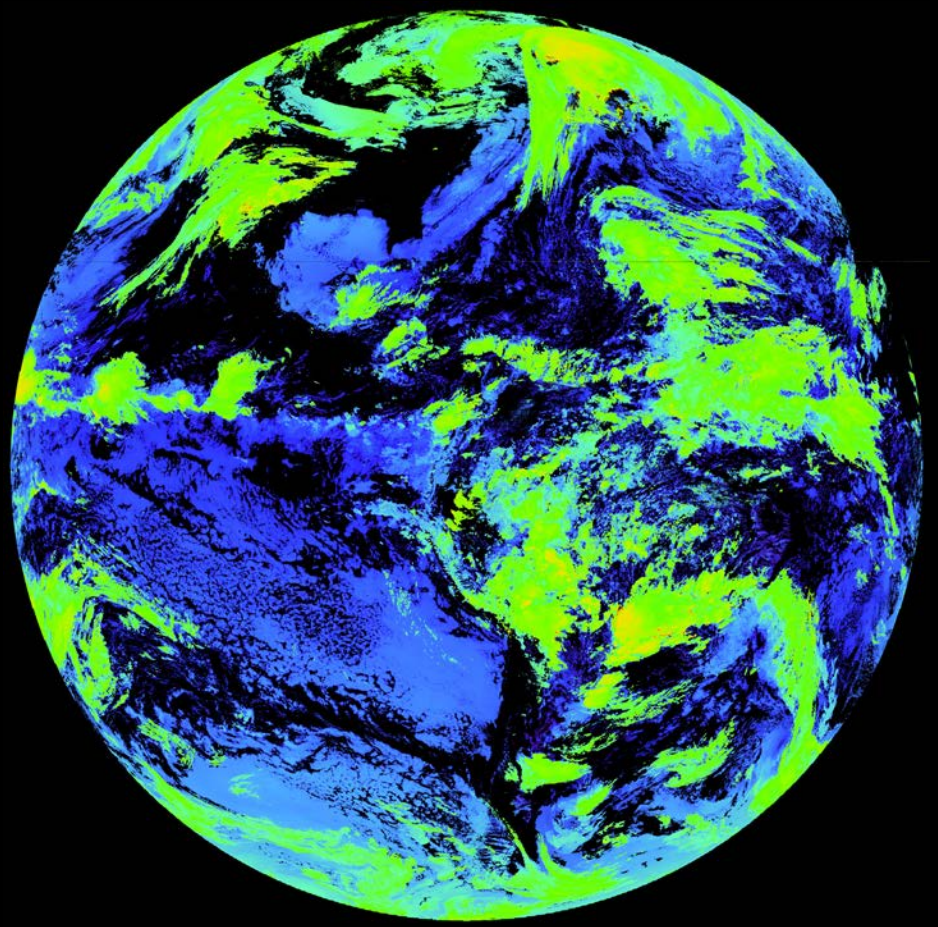


Figure 1. Colorized rendering of ABI Band 7 (Shortwave Window, 3.9 μm, 2 km resolution), GOES-East (GOES-16), NOAA/NASA, December 12, 2024, 17:30:20 UTC. The Shortwave Window Band has a variety of applications including fire detection, cloud particle size retrievals, and differentiating between liquid water and ice clouds. Received by Pixel Earth (Eric Rannestad and Justin Booz, Cambridge, MA, 2024).

Figure 2. Eric Rannestad and Justin Booz, Pixel Earth, installation view, Cambridge, MA, December 2024.

they interpret, is a history of power as much as a history of science.

Pixel Earth treats our numbness to this sensing infrastructure as a structural condition. The planetary nervous system operates below the threshold of ordinary attention where operational images upon operational images stack in a chain that finally reaches an end user. The installation attempts to interrupt that condition before the layers of modeling, forecasting, and commercial mediation that normally determine who receives what the satellite sees.

The GOES satellites occupy a peculiar position in time. Stationed at a distance where neither Earth's gravity nor its escape velocity will resolve them, they will remain in their current orbits for approximately five billion years. GOES-16 will be exactly where it is relative to earth long after every climate model it has informed has run its course, after the institutions that launched it no longer exist, and after the crises it was built to monitor materialize or not. As an artifact of the public forecast era, it outlasts the era that produced it.

Figure 3. Rendering of Pixel Earth installation in Cambridge, MA relative to GOES East 35800 kilometers away.

Figure 4. Display of live images received from GOES-East (GOES-16), NOAA/NASA, by Pixel Earth (Eric Rannestad and Justin Booz), Cambridge, MA, 2024.

Figure 5. Trackable objects in orbit around Earth. Image Credit: European Space Agency

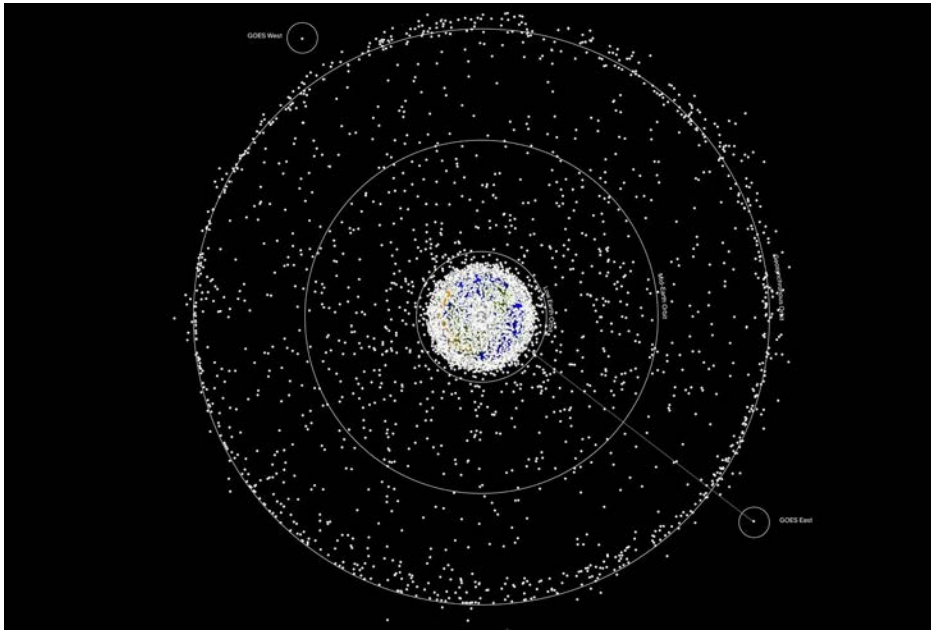


Figure 6. GOES East and GOES West relative to different key orbital zones.

The images produced by GOES-16 are not primarily made to be seen and consumed by the public. They are operational images in Jussi Parikka's sense: images that function within technical systems, feeding forecast models, training algorithms, pricing risk, and driving institutional decisions without passing through human perception in any meaningful way. As Parikka develops the concept, operational images do not represent an object but are part of an operation (Parikka, 2023). The RGB composite is just one type of image that the installation recieves and projects. These other bands, and the rgb composite are all part of an image system whose real outputs are numerical and computational. To project it onto the ground is to pull it out of its operational circuit and into the domain of the visible.

The pixel is the output of a system whose design decisions, from orbital placement to sensor wavelength to data licensing, encode specific political and economic arrangements into the act of seeing the planet. We encounter its outputs through weather apps, flood maps, and insurance premiums, while the hardware and the power relations that produced those outputs recede entirely from view. Pixel Earth stages the encounter that the apparatus normally forecloses before the chain of institutional mediation begins

Footnotes

[1] McLuhan, Marshall. "The Gadget Lover: Narcissus as Narcosis." Understanding Media: The Extensions of Man. MIT Press, 1994, pp. 41–47.

[2] Collis, Christy. "The Geostationary Orbit: A Critical Legal Geography of Space's Most Valuable Real Estate." The Sociological Review, vol. 57, no. S1, 2009, pp. 47–65.

[3] Parikka, Jussi. Operational Images: Redefining the Military Visual. University of Minnesota Press, 2023.

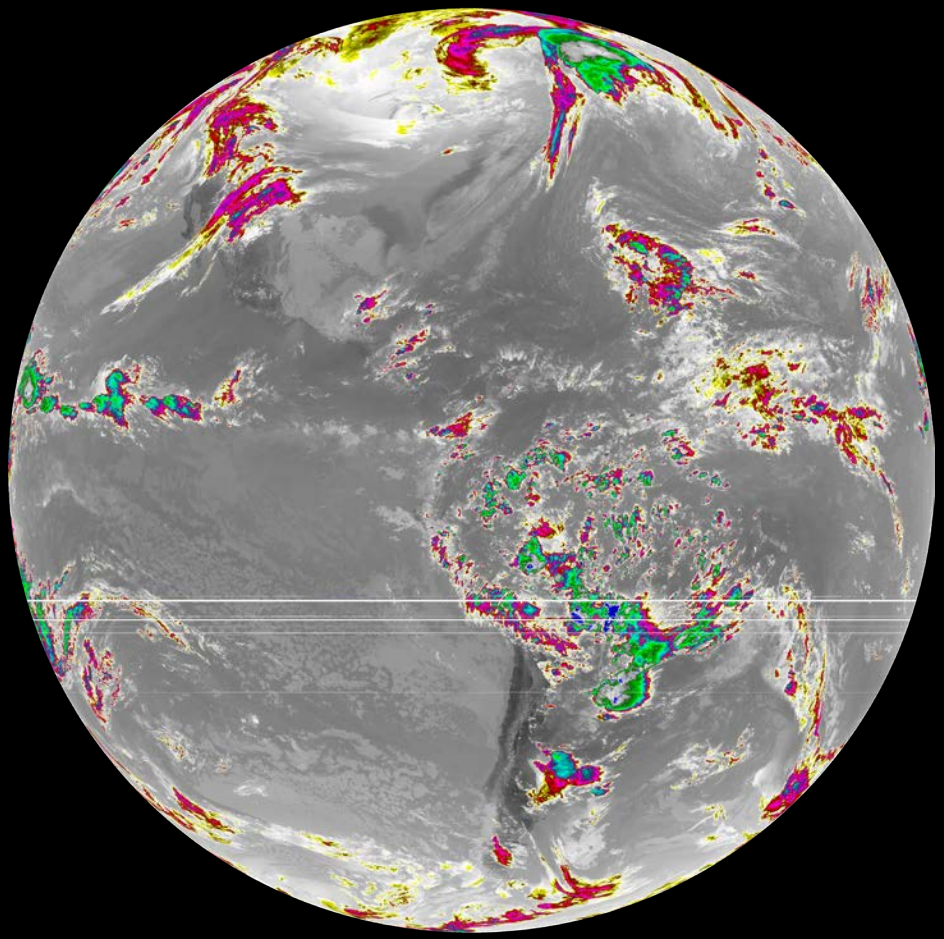


Figure 7. ABI Dirty Longwave Window RGB composite (CIRA), GOES-East (GOES-16), NOAA/NASA, December 12, 2024, 21:00:20 UTC. The Dirty Longwave Window composite uses thermal infrared bands to distinguish cloud-top temperatures, convective storm structure, and cloud phase. Received by Pixel Earth (Eric Rannestad and Justin Booz, Cambridge, MA, 2024).

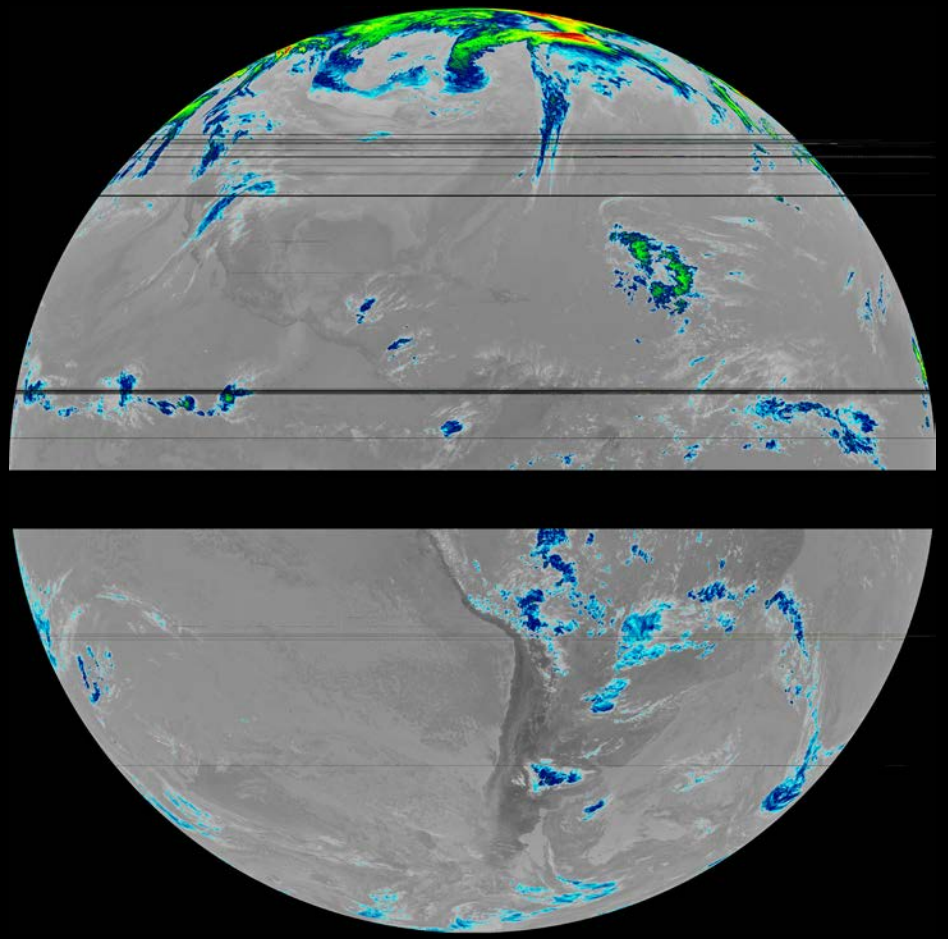


Figure 8. Colorized rendering of ABI Band 7, the Shortwave Window Band of GOES East. Recieved in the 2024-12-12_17-30-20 data packet by Pixel Earth installation. The 3.9 µm "Shortwave Window" Band at 2 km resolution. It has a variety of applications including fire detection, cloud particle size retrievals, and differentiating between liquid water and ice clouds. Recieved in the 2024-12-12_17-30-20 data packet by Pixel Earth.

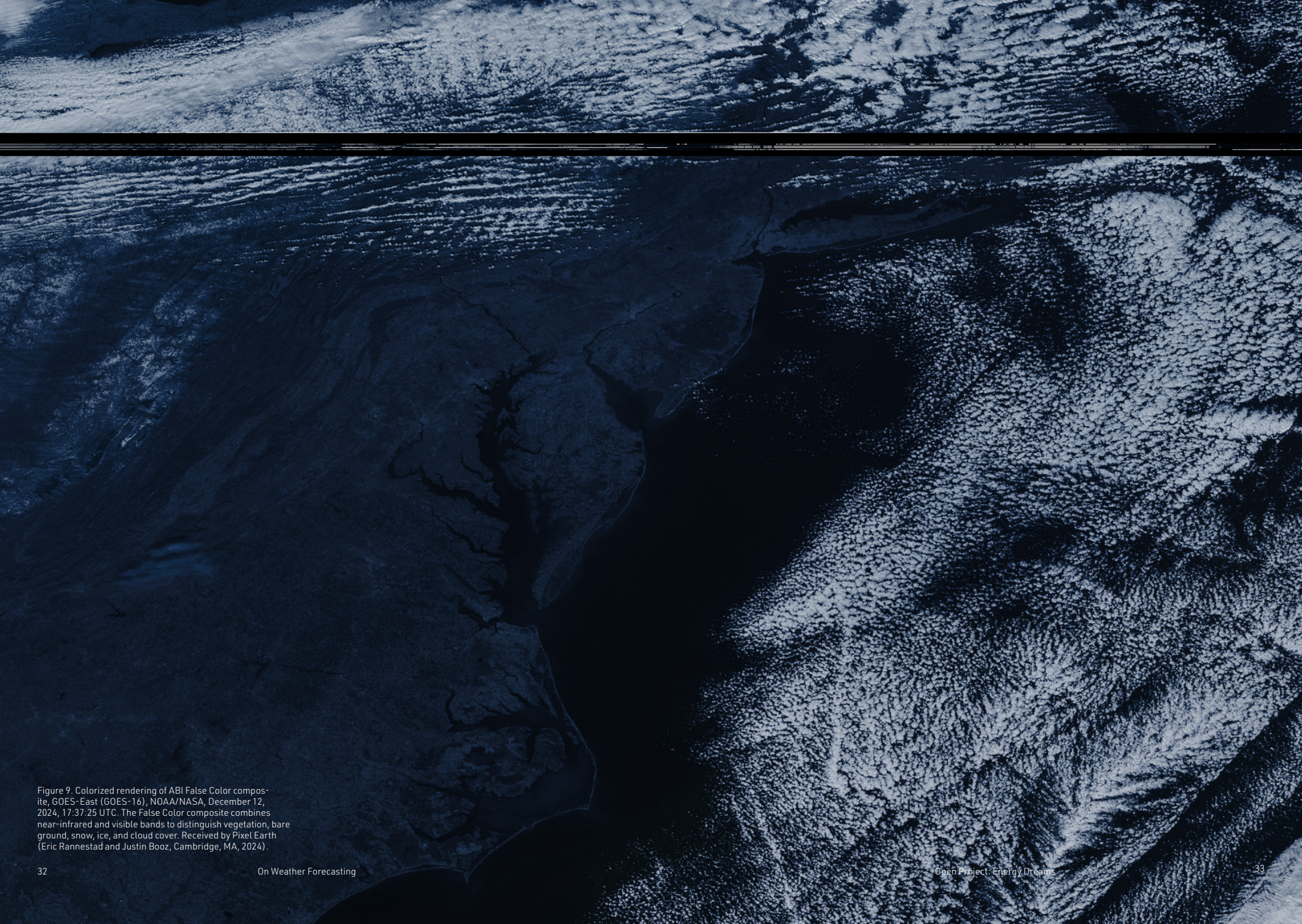
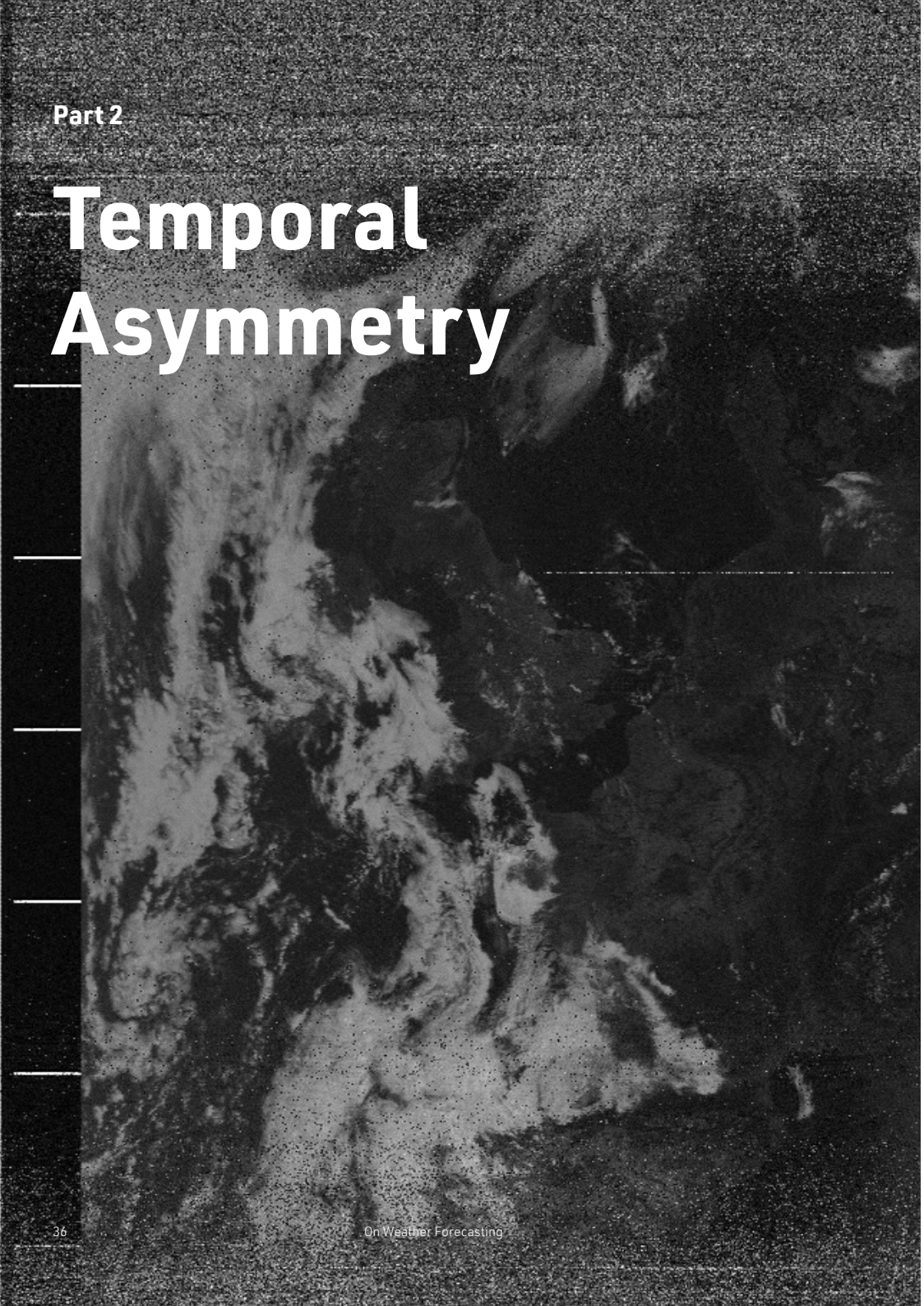


Figure 9. Colorized rendering of ABI False Color composite, GOES-East (GOES-16), NOAA/NASA, December 12, 2024, 17:37:25 UTC. The False Color composite combines near-infrared and visible bands to distinguish vegetation, bare ground, snow, ice, and cloud cover. Received by Pixel Earth (Eric Rannestad and Justin Booz, Cambridge, MA, 2024).

Figure 10. Eric Rannestad and Justin Booz, Pixel Earth, installation view, Cambridge, MA, December 2024.



Part 2

Temporal Asymmetry

The goal of this section is to describe the function of the forecast in the context of recent economic theory. Specifically, this section describes recent shifts in ownership of the forecast as a condition of capitalism's drive to create and maintain volatile conditions for speculation.

Driving this point is a cycle of rent-seeking and arbitrage as co-constructive functions of financial capitalism. This section identifies these forms of capture and exploitation as the extractive and colonial mechanisms of our time, and also an extension of the forces from which the western forecast emerged. Through the gap between proprietary weather forecasting models and that which is publicly available grows even wider. Those with the predictive edge can extract value from the gap between public and private value assessment through an array of market moves.

Future of Futures

Fundamentally, the weather forecast is an attempt to deal with the uncertainty of time. It produces an image of the future that can be operationalized to enact a certain kind of present.

In the shift toward a private forecasting apparatus, the ability to control its constitutive layers makes its information about the future excludable. The financialization of daily life [1] and the forecast's deep integration with economy then makes this knowledge rival, and rival in the sense that sharing possession of that knowledge makes it less valuable for all others who possess it rather than depleting it as a resource in any physical way. Exclusivity is not just a feature of how the private forecast is distributed, but is intrinsic to its value as a financial instrument and temporal product to be traded. The private weather forecast's role can then be understood as a device for producing temporal asymmetry, that is, to produce a gap between the public and the private image of the future.

This understanding of the forecast's value is built upon an understanding of economy as an emergent social device for dealing with the uncertainty of time. Elena Esposito in her book The Future of Futures: The Time of Money in Financing and Society builds her formulation of financial capitalism around this understanding. [2]

"The economy is not simply concerned with the acquisition of goods, but is instead focused on the dynamic connection of the scarcity of goods and the scarcity of money. It is for this reason that the economy is time, and, more specifically, future time. It isn't a question of the technical problems of obtaining resources, but of the temporal problems of the distribution and the absorption of uncertainty."

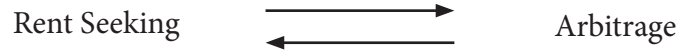
In this sense, money and its exchange allows for the deferment of decisions into the future. It converts present value into a claim on something that remains unknowable. Money, credit, and other representations of time emerge from this management of the unknown, unraveling into insurance and nth-order abstract positions (derivatives), and positions on positions (CDOs) that together make it possible to buy and sell risk on risk on risk. These devices claim to make the world more certain for their holder, but as Esposito observes, "their circulation actually increases uncertainty, which can be transferred to others when one buys certainty." [2, p. 112] Each actor is observing the other observing the other, and purchasing a more certain future only transfers their uncertainty somewhere else in the system.

This is a kind of structural collective action problem that financial capitalism cannot resolve from within its own logic. Within such a system, the only rational pursuits are to either observe the trends of the system itself with complete disregard to ground conditions, or possess knowledge of the future before anyone else. Both of these paths of action make the weather forecast rich substrate for the operations of financial capitalism and are the main structural conditions motivating its capture.

Temporal Asymmetry

The private weather forecast offers the means to produce excludable knowledge of atmospheric events before they are publicly priced. Financial operators with the better forecasting model can know the exposed sectors before the market and can move to capture value from this knowledge by taking advanced positions in those sectors. But the financial operator can also capture their advantage at higher financialized orders by interpreting how other operators will respond when that forecast knowledge becomes public. In other words, they can take another speculative position on the market's response rather than simply ahead of the event itself. In this sense, the exposed sectors of a forecast event extend into other abstract representations of risk and exposure for that event in time, producing even more surface area for the financial operator to exploit. Information produced by the private forecast participates across the financialized field of risk, at all orders of abstraction.

In any case, the actor who holds exclusive knowledge of the future can convert it into a positional advantage, extracting value from the gap between what they know and what the market has not yet priced. The mechanism through which value is extracted takes two co-constructive forms. The first is rent-seeking: the capture of a public good by restricting access to it, converting a non-rival and non-excludable resource into a site of extraction. The second is a kind of temporal arbitrage: the exploitation of the gap that such capture produces. [3]



The privatized forecast is both the object of this cycle and its instrument. The capture of the public sensing and model infrastructure is the rent-seeking operation: a non-rival and non-excludable resource converted into a proprietary marketplace that is both rival and excludable. This conversion of a public good into a site of rent extraction allows for this kind of arbitrage: the purchase and sale of energy positions, weather derivatives, insurance instruments, and long-range climate risk products, each extracting value from the gap between what the private model knows and what the public forecast does not yet show.

Futures Cone Capital

A particularly interesting artifact of the economy's fixation on the management of temporal uncertainty is the proliferating use of the "futures cone" within the LinkedIn-osphere. The futures cone emerged as a conceptual device from the field of future studies in the 1970s, resurfacing in the 1990s with various academic iterations before exploding into mainstream circulation in 2020. [4] While intended as a device for relating to the multiplicity of possible futures, of limitation, and perspective, it has been repurposed as a mantra of capitalism for hedging, uncertainty, speculation, and forecasting. [Figure 1]

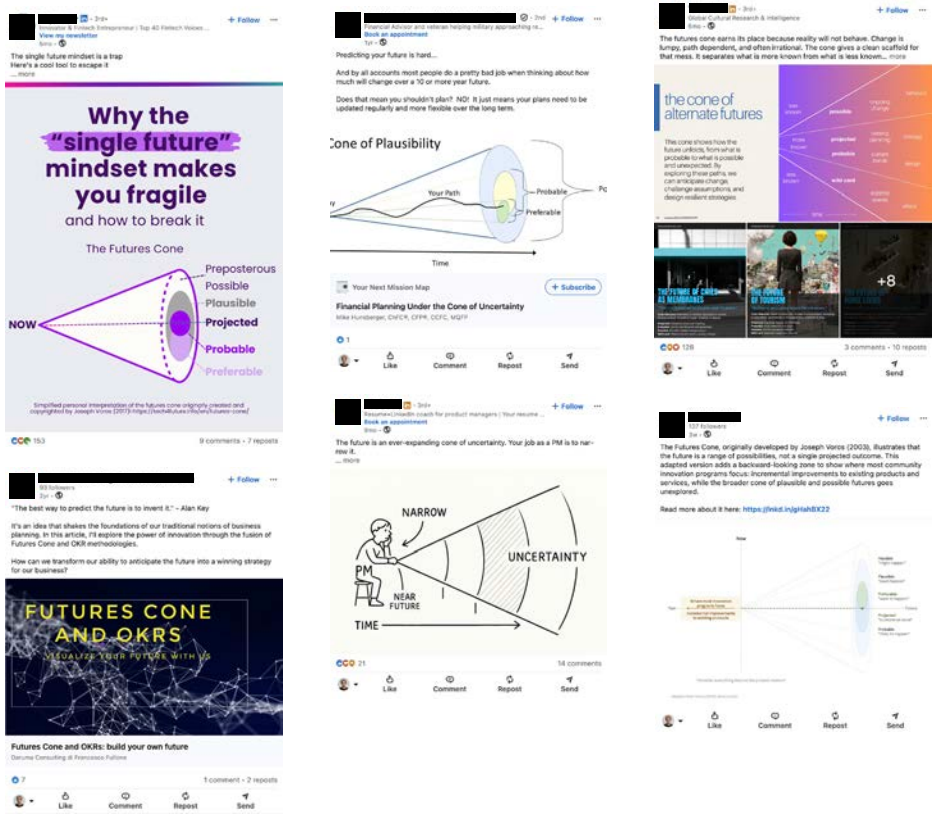


Figure 1. Linkedin posts about "future cones" from fintech entrepeneours, product management coaches, investors, financial advisors.

When this position of the future is projected onto Esposito's financial economy of observers observing the observer, all with the interest of buying future certainty, we develop a relational panopticon of flocking agents, orienting themselves in self-conscious and increasingly abstract relations to each other. The ordering logic of these conic agents is nonsensical and oriented toward the goal of predicting the movement of the other.

In the sense that these agents self-organize, they do so according to their internal rules of capital accumulation, as money defers decision making about the future, and because the future is fundamentally uncertain, one can never have too much money. So, as a flock, these agents lift, [3] or in the case of the 2008 Financial Crisis, one agent follows another which follows another, into the ground.

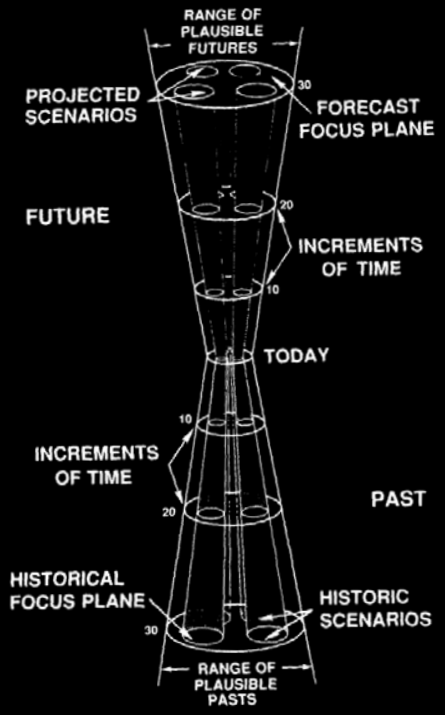
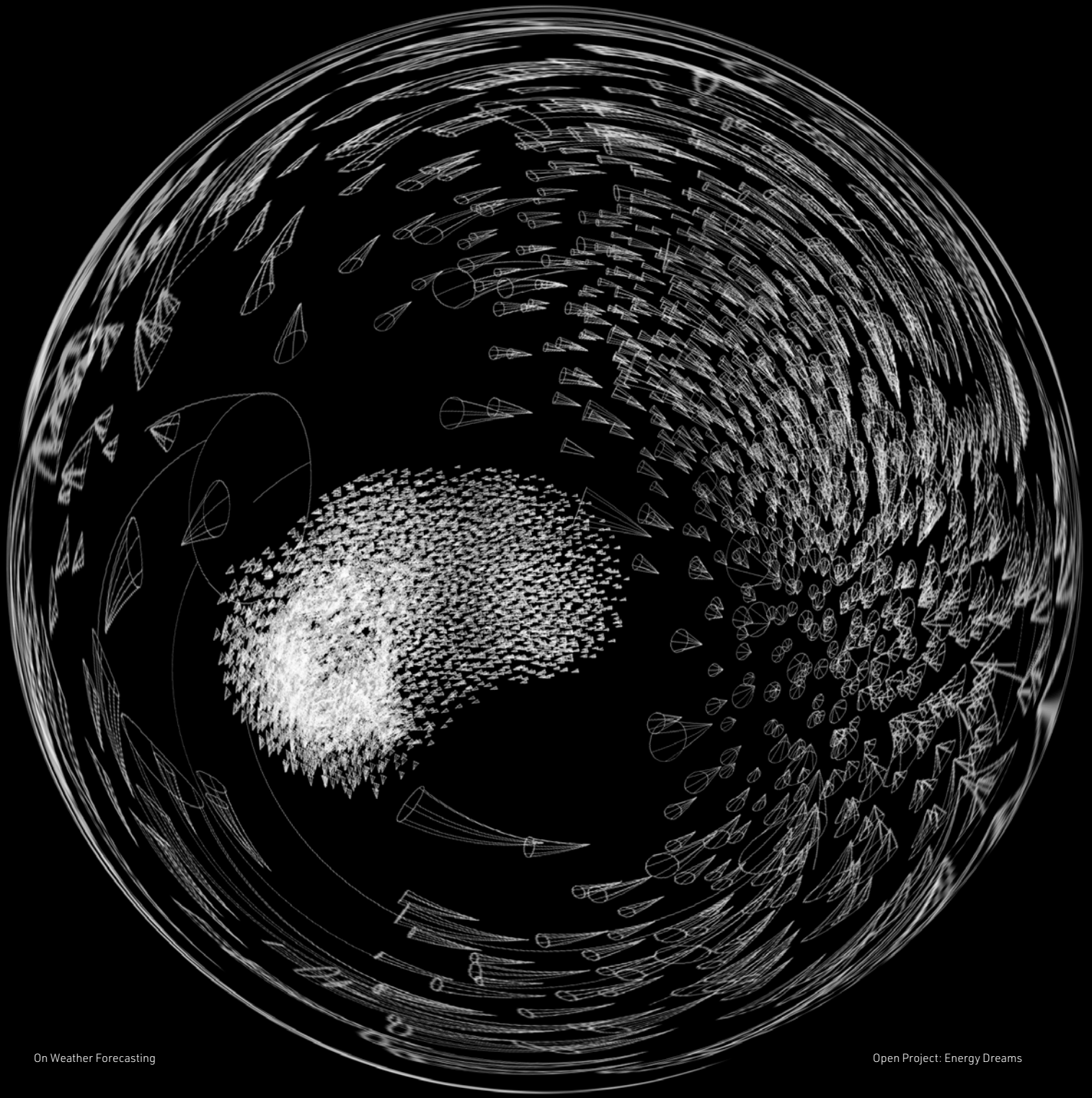
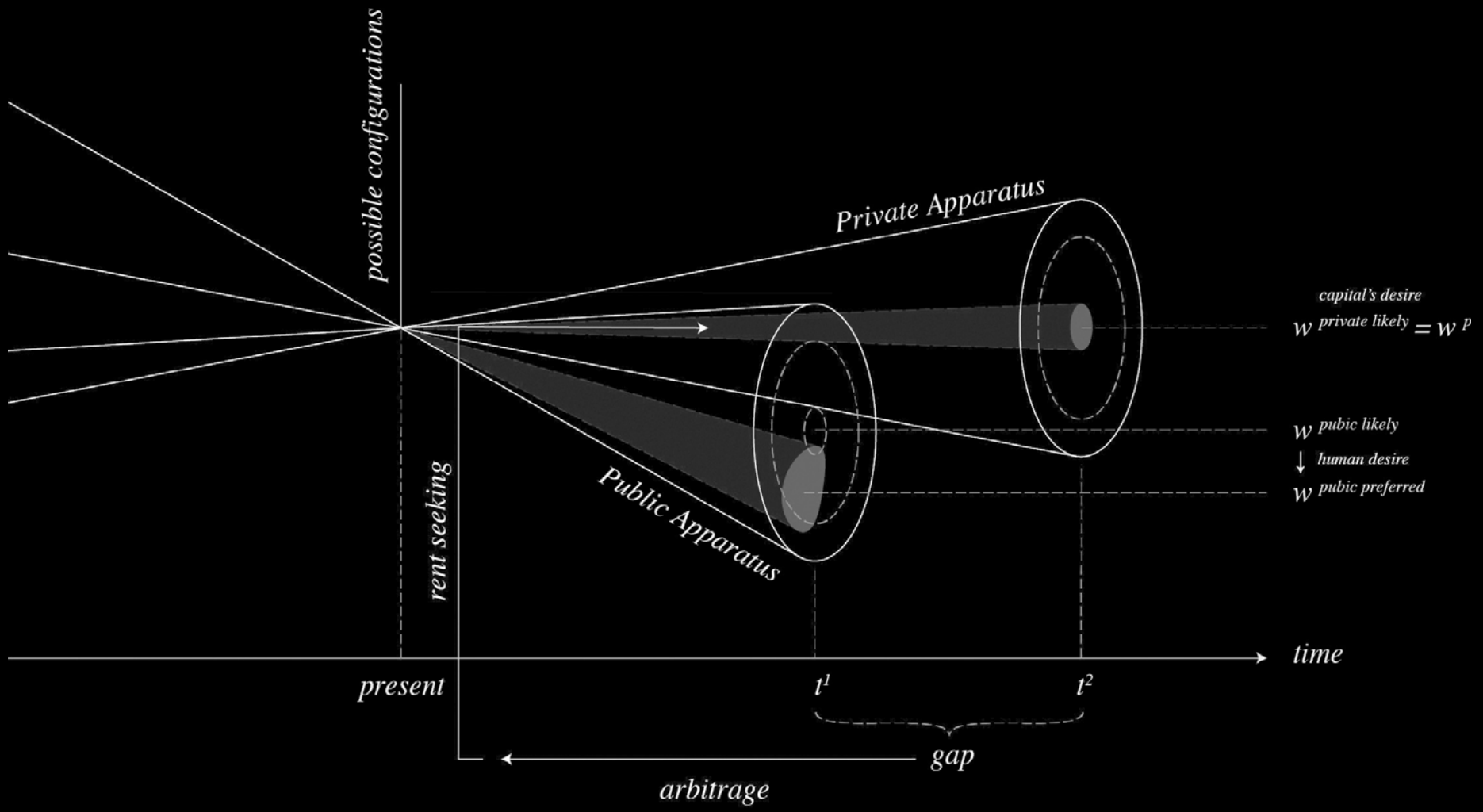


Figure 1. The Cone of Possibilities by C. W. Taylor, 1990. Taylor developed the "Cone of Plausibility" while at the U.S. Army War College



Coopting the futures cone as a graphical device for representing the cuts and perspectives of our two forecasting apparatuses, the public model and the private earth systems model, we can visualize our temporal gap, mechanism of arbitrage (buy, hold, sell) and rent-seeking (capture through lobbying, entrenchment of power, market failure, etc). Another thing that can be observed in this diagram are the likely and preferred futures of each apparatus.

Capital's preferred configuration of the world is the one at the center of its homogenous relational vortex, the future that is most likely to exist in the swirling of its operations: an uncertain future that is exactly as planned. Capital otherwise has complete indifference to what that may be. On the other hand, the public apparatus attempts to steer toward a configuration of the world that is different from the most likely configuration, whereby these preferences are dictated by the social, cultural, economic, and political forces that steer it.



Phenomena

The privatization and financialization of the forecasting apparatus each intra-act conditions in the world. This paper organizes those conditions as phenomena: things that come into being through the apparatus's operation. The forecast produces a particular image of the future that is operationalized through the economic structures described above. Esposito makes a parallel argument about financial markets as systems of second-order observation: that the observer is never neutral, and markets observing their own movements produce conditions they otherwise would not. The financialized forecast, in attempting to measure and manage an uncertain future, makes it in its image. [2][5]

These phenomena are organized by time because time is the shared vocabulary of the forecast and of financial capitalism. Both are oriented toward time as their primary substrate. The short time of weather derivatives and intraday energy trading, the long time of catastrophe bonds and climate risk products, the ambition of time control in technocratic proposals to manage the atmosphere itself, and the time dissociation experienced by those whose relationship to natural life and agency is disrupted by these systems: each represents a different register in which the entanglement of the forecast and financial capitalism produces legible effects. The following sections move through these registers in turn.

Footnotes

[1] Martin, Randy. Financialization of Daily Life. Philadelphia: Temple University Press, 2002.

[2] Esposito, Elena. The Future of Futures: The Time of Money in Financing and Society.

[3] Poliks, M., Trillo, R.A. Exocapitalism: Economies with Absolutely No Limits. Berlin/Nicosia: Becoming, 2025. In a more radical interpretation, Poliks and Trillo describe arbitrage as "the kernel of capitalism, the axiomatic of capitalism," and fundamentally a temporal operation: "neither the underlying asset nor the currency medium through which that asset is abstracted change in any manifest way, but somehow value is generated simply by virtue of the temporality of exchange." (p. 66)

[4] Theunissen, Romano. "The Futures Cone Reimagined: A Framework for Critical and Plural Futures Thinking." Journal of Futures Studies (In Press, February 3, 2026). jfsdigital.org/the-futures-cone-reimagined-a-framework-for-critical-and-plural-futures-thinking/

[5] MacKenzie, Donald. An Engine, Not a Camera: How Financial Models Shape Markets. Cambridge, MA: MIT Press, 2006.

Ruleset Paintings

A model describes a spatial structure whereas a simulation releases that str
ture into time, stepping forward through successive states to produce outp
that cannot be derived analytically from the rules alone. A simulation is an
ontological subset of the model: the model released into time. It is processu
al. It enacts what a system does rather than describing what it is. It is run a
occupies time. Where the model is a condition of possibility, the simulatio
is its actualization, producing structure that did not exist before the proces
generated it.

Edward Lorenz discovered a version of this working on early numerical
weather models in the 1960s, finding that the atmosphere's fluid dynamics
extraordinarily sensitive to initial conditions: small errors amplify exponer
ly, and deterministic forecast skill has a hard physical horizon of roughly tv
weeks. This discovery became the foundation of chaos theory: that certain
terministic systems, systems governed by fixed rules with no randomness b
in, are nonetheless unpredictable beyond a short horizon because vanishin
small differences in starting conditions produce radically divergent outcon
over time. The movement of atmosphere is the paradigmatic case for the fi
While data and computing power matter for prediction, the physics of the
system itself resists the kind of stable, recoverable relationship between init
conditions and future states that classical modeling assumes.

Even some some simple one-dimensional cellular automata exhibit this be
havior. Cellular automata are grid-based discrete mathematical systems wh
cells change their internal state based on the states of its neighboring cells.
These systems are distributed forms of computation and have the capacity
produce unexpected and complex behavior. These computational models a
frequently used technique for modeling patterns and flows in nature, from
simulations, diffusion simulations, and predator prey models and many otl
contexts.

While the rules are fixed and local, the behavior that emerges through succ
sive time-steps cannot be read off the rules in advance. The system must st
through time to produce its structure.

This problem reveals the political nature of models and simulations. In the
of climate, knowledge is not discovered but constructed, through a lineage

sociotechnical infrastructure of instruments, institutions, and data practices that must be assembled before any model can run at all. The initial conditions of a climate model are not given by the world but produced by it, through reanalysis, interpolation, and standardization across unevenly distributed observational networks.

Volatility and noise are constitutive properties of the system and are generative of the signal. In the case of weather and climate, the atmosphere is a thermodynamic system far from equilibrium, the order it produces, weather patterns, storm tracks, seasonal rhythms, is always provisional, always one perturbation away from reorganization.

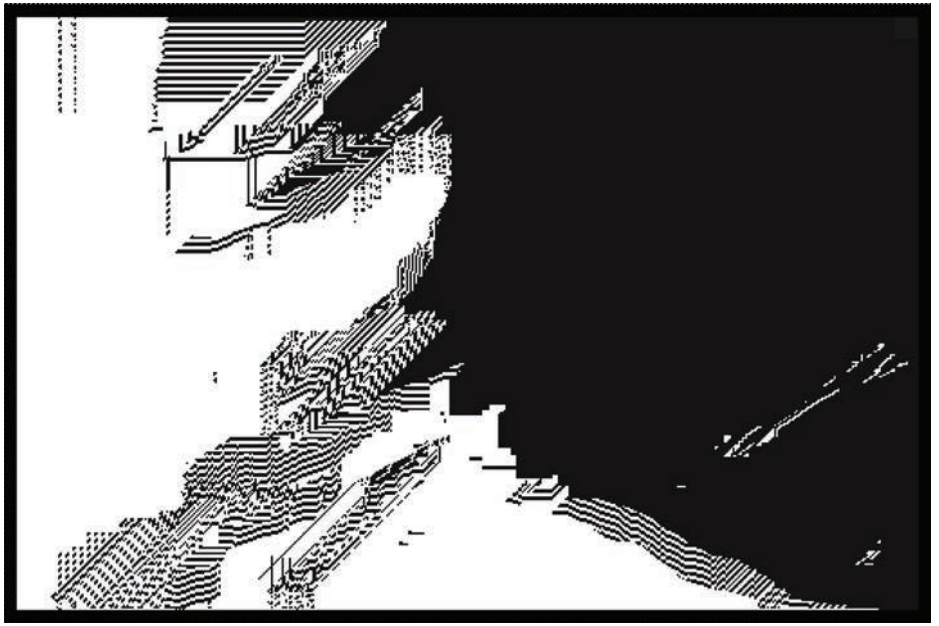
The Ruleset Paintings depicted here were completed in the Spring of 2023. I develop these works by washing and lifting paint, in relation with the emerging network of marks. Running across the top of the painting is a one-dimensional cellular automata system, stepping through time.

The blue band of the painting was drawn with a machine, beneath this band is a hand-rendered watercolor painting. These two modes of representation produce a tension between a discrete representation of complexity, and a certain unknowable complexity. I understand them each as forms of simulation, and as reflections on our limited ability to fully know the emergent qualities of compounded systems.

The CA band in these paintings attempts to render a representation of this condition: it steps forward by fixed rules and produces something that reads as equal parts signal and noise, pattern is legible at certain scales but falls into randomness at others. The hand-rendered watercolor beneath this band serves as a rumination on this complexity and on representational control.

Footnotes

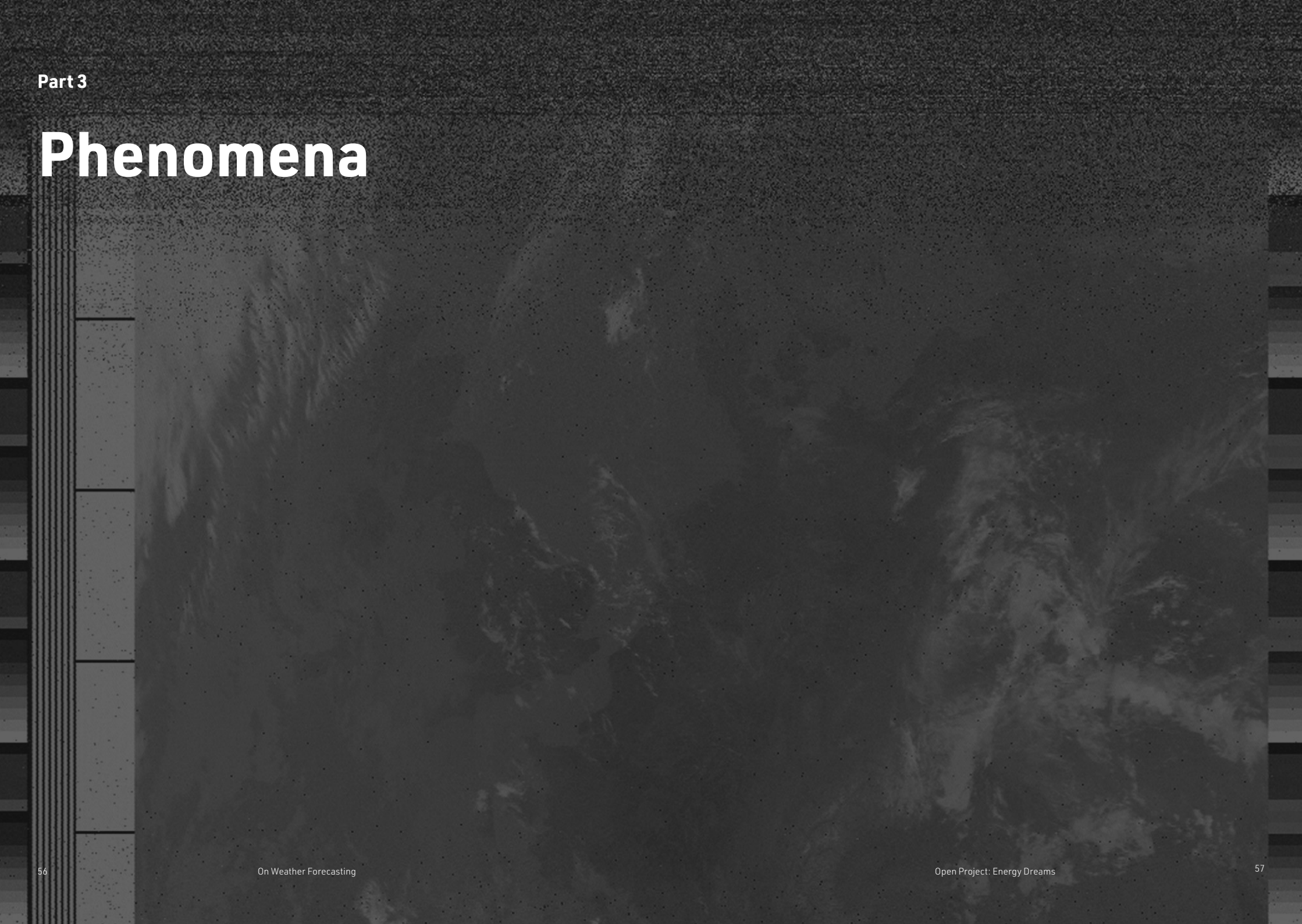
[1] Edwards, Paul N. A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming. Cambridge, MA: MIT Press, 2010



Ruleset Painting Tool
Web Application
2023

Part 3

Phenomena



Phenomena

Short Time

This section traces how the privatized forecast registers materially at short timescales: in the intraday energy market and the weather derivative. It argues that the gap between private and public forecasts produces a structural arbitrage mechanism, driving an arms race in proprietary modeling where marginal forecasting edges translate into significant returns at scale. The costs of this arrangement are absorbed by ratepayers, small utilities, and the public. Winter Storm Uri is taken as the contemporary case in which this asymmetry registered most violently.

These are short-time registers of longer extractive logics. High-frequency trading and intraday power markets are expressions of capitalism's core mechanics: how arbitrage, the buy, hold, sell are preticated on assymentric information about the volatility of price, and that capital attaches itself to risk and volatility as a tradeable asset.

The information asymmetry produced by the privatization of forecasting is not abstract. It is operationalized through specific financial instruments that trade directly on the gap between proprietary and public atmospheric knowledge.

The financialization of weather at short timescales is exemplified by the weather derivative. Weather derivatives are financial contracts that enable companies to trade on non-extreme weather risks, paying out when certain environmental conditions are met. This asset class emerged in the US energy sector in the mid-1990s when Enron, unable to insure against low-consumption winters, invented a new market modeled on oil and gas futures trading.

The weather derivative profits from temporal advantage, knowing what the atmosphere will do before the market prices it in. It does not trade on the weather itself. The contract pays out when the temperature index crosses a threshold, regardless of what actually happens on the ground. The model becomes the referent. Capital trades on representation: a negotiated sensory truth assembled from phone data, airport sensors, official records, and proprietary models. This is the mechanism through which price is decoupled from material value through the production of intermediaries.

These speculative financial instruments eventually land, often far from their source. The contemporary US energy grid offers one such material register of this financialized layer of the forecast.

The Energy Grid

Over the last several decades the energy sector has fragmented from a state-controlled industry into a more competitive and decoupled one led by variable renewable energy sources such as wind and solar. These smaller variable sources of power now occupy a growing share of production capacity [cite stat]. As Kuppelwieser and Wozabal observe, "the weather-dependent and unpredictable nature of VRES production has increasingly shifted the focus to markets with a high temporal resolution that trade close to delivery when production forecasts are reasonably accurate."[1]

The wholesale electricity market operates through a two-stage structure: a day-ahead market, where energy is bought and sold based on forecasted demand and generation, and a real-time market, which adjusts in intervals as short as five or fifteen minutes as actual conditions diverge from the forecast. The spread between these two markets, between what the atmosphere was predicted to do and what it actually does, is where arbitrage occurs.

Kuppelwieser and Wozabal demonstrate this mechanism precisely. They design an algorithmic trading strategy that owns no power plants and has no electricity demand of its own, generating profits purely from having better forecasts of wind and solar output than the rest of the market. The strategy works by exploiting the gap between what was sold on the day-ahead market, priced on yesterday's weather forecast, and what the atmosphere actually delivers the following day. They find that this gap is large enough and predictable enough that publicly available forecast data alone can be used to generate significant returns. A perfect forecast would increase profits by an order of magnitude, from €200,000 to €2 million annually for a single product category. The authors conclude that these conditions are likely to "trigger an arms race in forecasting with market participants trying to capitalize on ever improving forecasts," analogous to the arms race for speed that has come to characterize high-frequency financial trading.[2]

Winter Storm Uri

When Winter Storm Uri struck Texas in February 2021, wholesale electricity prices surged from around $50/MWh to ERCOT's cap of $9,000/MWh, a 180-fold increase. At least 246 people died, 4.5 million homes lost power, and Texans collectively owed roughly $37.7 billion in electric bills. The natural gas industry earned $11.1 billion in profits over the five-day storm. The distribution of those profits reveals the information asymmetry at work. Kinder Morgan earned approximately $1 billion and explicitly acknowledged advance preparation based on weather intelligence, dispatching workers and backup generators ahead of the storm to its gas storage and pipeline facilities. Energy Transfer reported expected gains of $2.4 billion for the year. Macquarie Group saw its profit outlook boosted by roughly $317 million USD. Goldman Sachs, Vitol, and BP also profited enormously while declining to specify figures. Meanwhile, CPS Energy, San Antonio's municipal utility, received a gas bill of $700 million for the week. Luminant spent $1 billion buying electricity at the cap price. Oklahoma Natural Gas incurred $1.4 billion in debt, now charging customers $7.80 per month for 25 years to securitize costs.

The pattern of who profited and who paid maps directly onto the question of who held the better forecast.

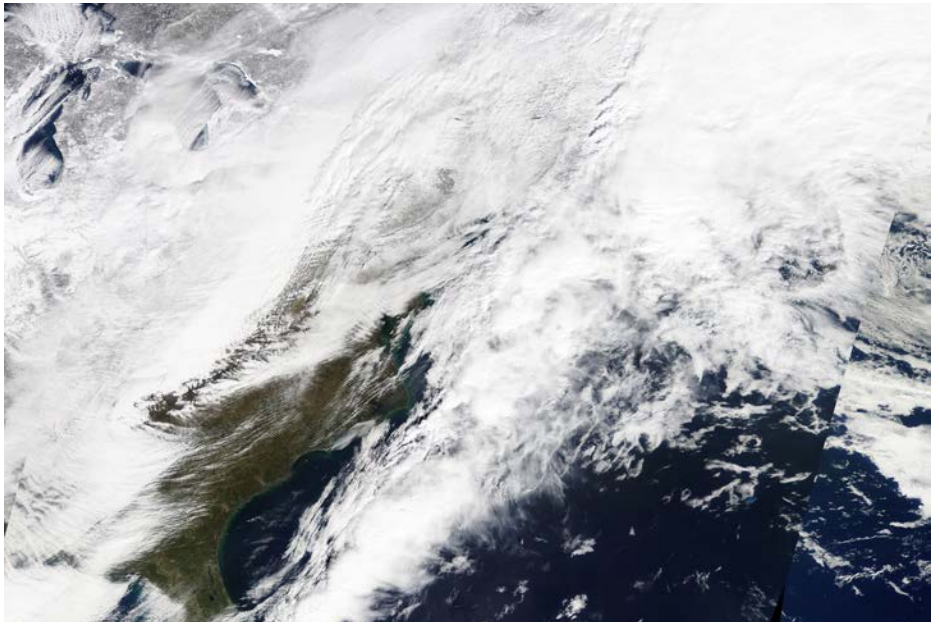


Figure 1. Winter Storm Uri caused catastrophic and widespread impacts across the Southern United States, particularly in energy markets.

Footnotes

[1] Thomas Kuppelwieser and David Wozabal, "Intraday Power Trading: Toward an Arms Race in Weather Forecasting?" OR Spectrum 45 (2023): 58.

[2] Kuppelwieser and Wozabal, "Intraday Power Trading," 61.

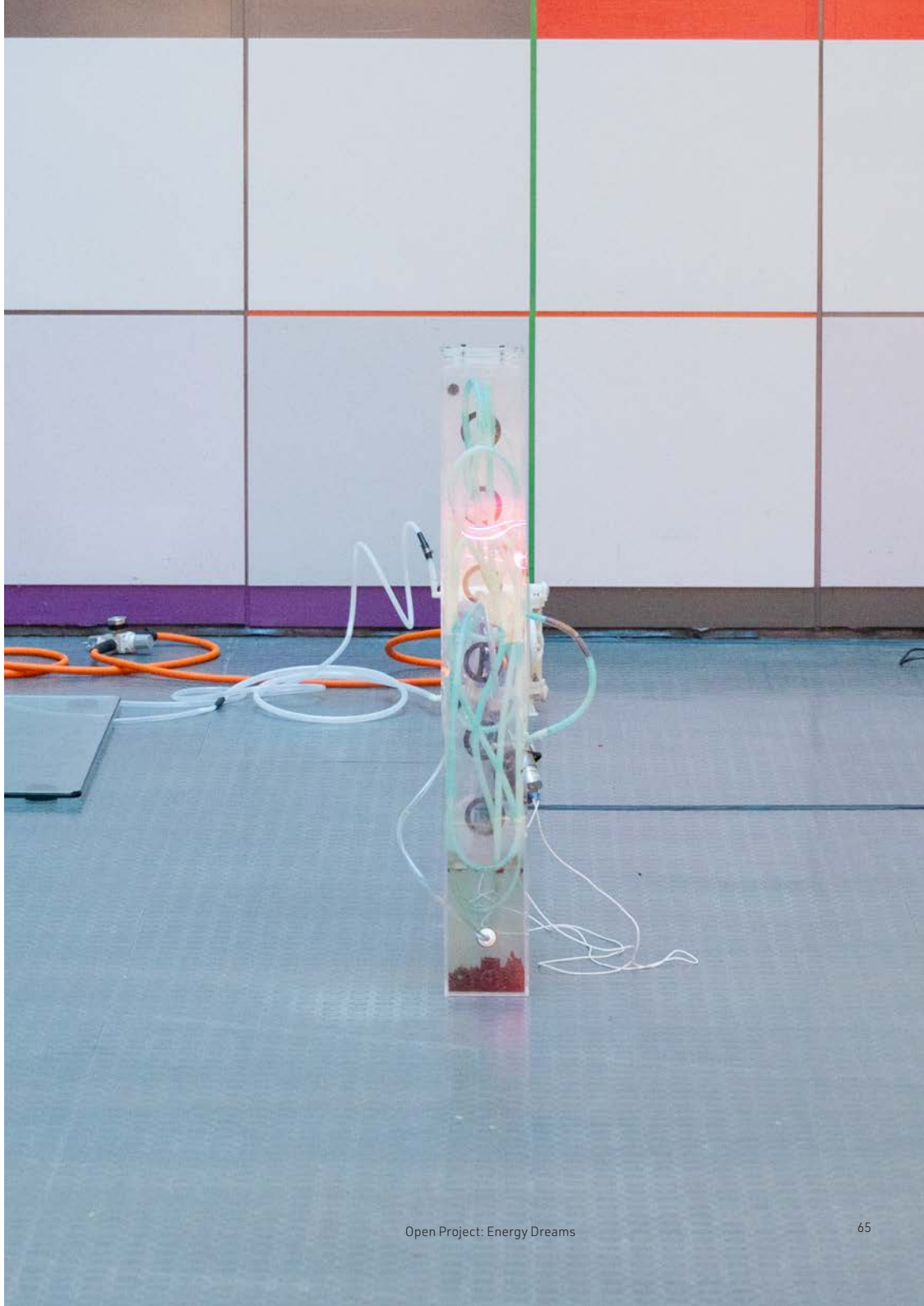
Tailings

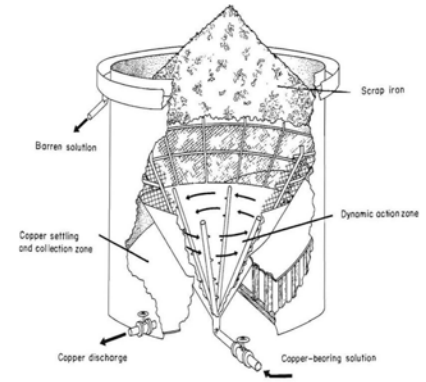
Tailings, and its associated tanks (Accumulators 01-04) are a series of works that describe the extractive geographies (land, water, mineral, labor) that supply our digital infrastructures. These infrastructures, from the planetary telecommunications and survaillence system, to hyperscale data centers, all require rare earth metals, cobalt, copper, water, energy and a vast array of other material inputs. The project specifically looks at the proliferation of technical infrastructure and how the economic model that supplied its growth has begun to ingest the tailings of its own waste.

In the United States, accumulated mine tailings from copper, cobalt, and coal extraction are increasingly recognized by the State as latent deposits of rare earth metals—resources now critical to data centers, satellite infrastructure, and military technology. The acidic runoff from these mines dissolve and suspend metals in high concentrations, turning industrial waste into a new frontier of extraction. Chemical leaching processes, bioaccumulation systems, and nanoscale filters are being developed to selectively harvest these residues, effectively mining the mine's own waste. As our computational and telecommunications infrastructure begin to consume this second-order material, the model of extraction folds inward, further entering its own synthetic space

Tailings initially grounds itself in the material processes and metabolic flows of Butte, Montana. Once the epicenter of global copper production, Butte is now home to the Berkeley Pit: an acidic lake of industrial waste and popular example of environmental catastrophe at the hands of industrial capitalism. In recent years, U.S. efforts to secure new sources of critical minerals and maintain geopolitical power have reframed Butte's acidic water bodies as an unexpected asset. As virtual space accelerates, nodes of its supporting material infrastructure surface with unusual clarity in Butte: century-old mine tailings are re-mined for rare earth elements, dissolved copper precipitates onto scrap iron, and a 400-MW data center is built along Silver Bow Creek.

Through staged circulatory models and various sedimentary flows, the project explores the logics of industrial capitalism, the mechanical gaze turning inward, loops, false loops, and the components parts of a metabolic model churning.





[Figure 1] Cutaway Diagram of Cone Precipitator for the reclamation of copper from Kennecott Copper Corp.

[Figure 2] Cutaway Diagram of Cone Precipitator for the reclamation of copper from Kennecott Copper Corp.

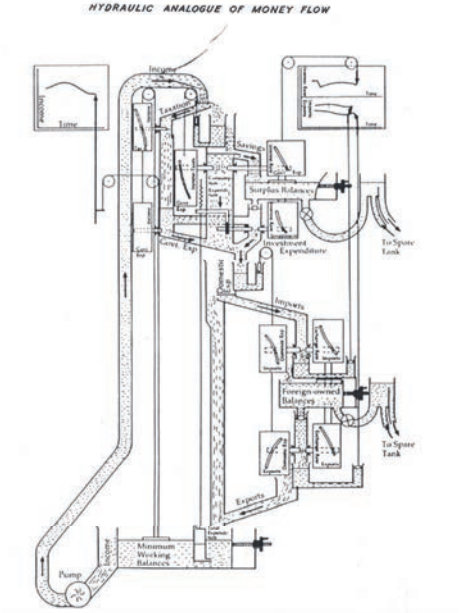
Each Accumulator Tank in the series is a sort of "metabolic quotation" of the Butte landscape and the models animating its governance. For example, In Accumulator 01, the work cites a historic metalurgic method of copper recovery from acid mine drainage. [Figure 1,2] The simple method employs a chemical reaction between dissolved copper and iron which has been used by mining companies and environmental remediation groups since the early 20th Century. As copper laden mine tailings contacts iron, the dissolved copper cements (plates) onto the iron in metalic form. This oxidization reaction grows copper nodules that are economical for collection, smelting, and sale. Copper, of course was and is fundemental to the telecommunications circuitry that pre-empted and sustained the information age. This reorientation of wastewater was a major operation in the Berkely Pit mining complex and a precursor to the rare earth metal recovery efforts being explored today.

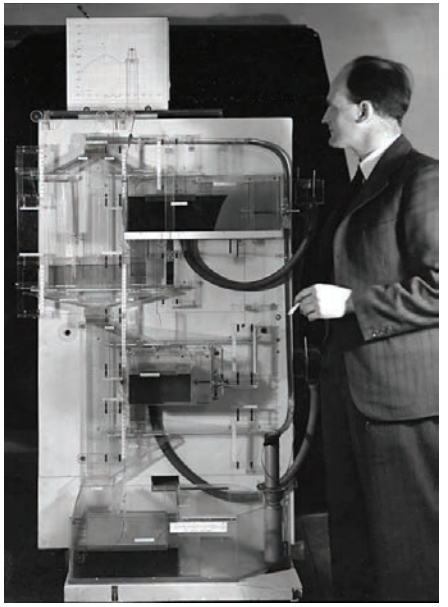
What this project renders visible are the material dependencies of an increasingly finacialized and self referential economy, one that registers planetary and financial logics within sedimentary layers.

The weather derivative, the intraday energy trade, the algorithmic position open and close in microseconds: but each runs on physical substrate of enormous spatial scale. These infrastructures are buried across geographies for

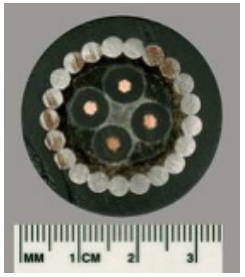
a fractional temporal edge. Data centers demand water, land, and energy in quantities that register on regional infrastructure. The rare earth metals in processors and satellites that produce and trade on atmospheric volatility first register in the economy as commodities, with their assigned value moving with speculative demand and supply informed by geopolitics and industrial capitalism.

Commodity prices, share prices, and industrial policy coproduce each other in a loop that oscillates between speculative price and ground condition. As cobalt prices climb, the cobalt belt of Idaho surfaced in speculative feasibility assessments; as institutional investment in EV and AI infrastructure drove copper futures ahead of actual demand, mines expanded across the American Southwest to meet a price signal that was itself partially a financial artifact. As US economic exposure to Chinese dominance of rare earth processing regis-

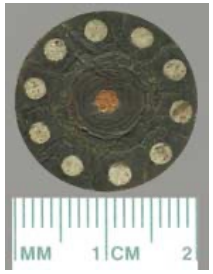




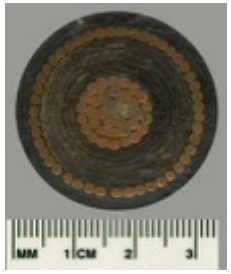
[Figure 3] The Phillips Economic Analog Computer, dubbed the MONIAC, a reference to ENIAC and later called the Phillips Machine after its inventor the economist Bill Phillips, demonstrates in a physical way the circular flow of money within the economy.



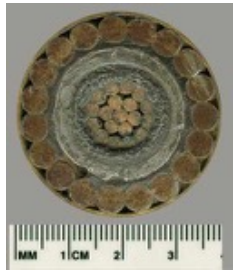
Single conductor telegraph cable
1861 Algeria-France
Armoured



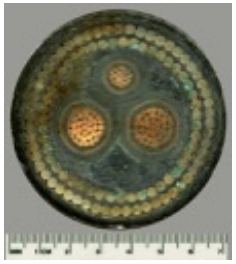
Simplex
Four conductor telephone cable
c. 1960
Armoured



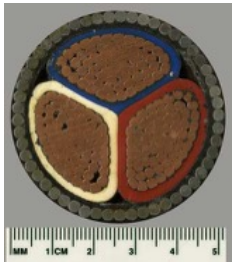
Callender's Cable
Two concentric conductors
Unarmoured



Unmarked
Single conductor, lead sheathed
Armoured, 19 wires



Siemens Brothers & Co Limited,
London
Three conductors
33,000 volt cable
River Plate Electricity Co.
Laid – 1901
Lead sheathed
Unarmoured



Henley Cable
W.T. Henley's Telegraph Works
Co. Ltd. London
3 x .4 sq.in. P.V.C. insulated
textile
bedded S.W.A. and served L.T.
cable
Armoured

Unknown
Three conductors, lead sheathed
Armoured, 45 wires
The 4" long sample of this cable
weighs over six pounds

Figure 4. Copper electroplating and plumbing experiments in the studio.

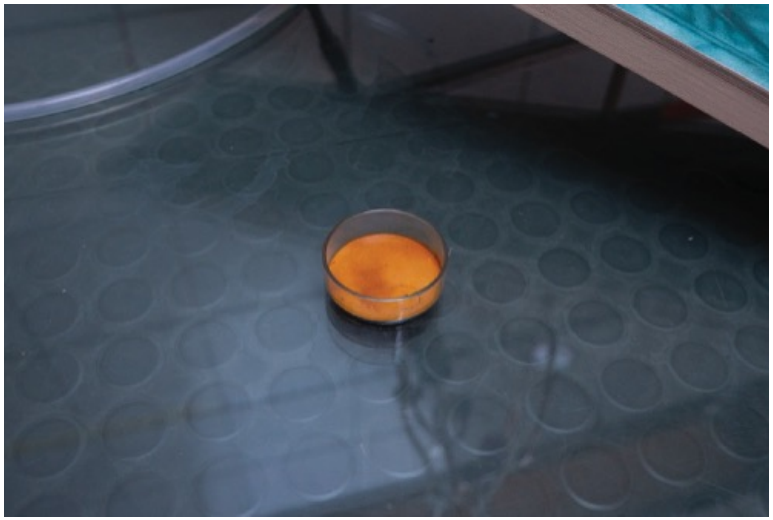
Figure 5. Photo of high-voltage transmission lines provide electricity to data centers in Ashburn in Loudon County, Virginia, in July 2023 by Ted Shaffrey/AP

tered as a geopolitical supply risk for technology and defense companies, the federal government used industrial policy such as the CHIPS and Science Act (2022) and the DOE Critical Minerals Strategy (2021) to address these financial risks. These policies are the principle force driving a nationwide search for productive waste, including funding pilot extraction facilities in Appalachia and Butte. The Defense Department grant to Montana Resources to pilot rare earth extraction from Butte's wastewater is the state underwriting a speculative position already taken by capital in response to geopolitical precarity.

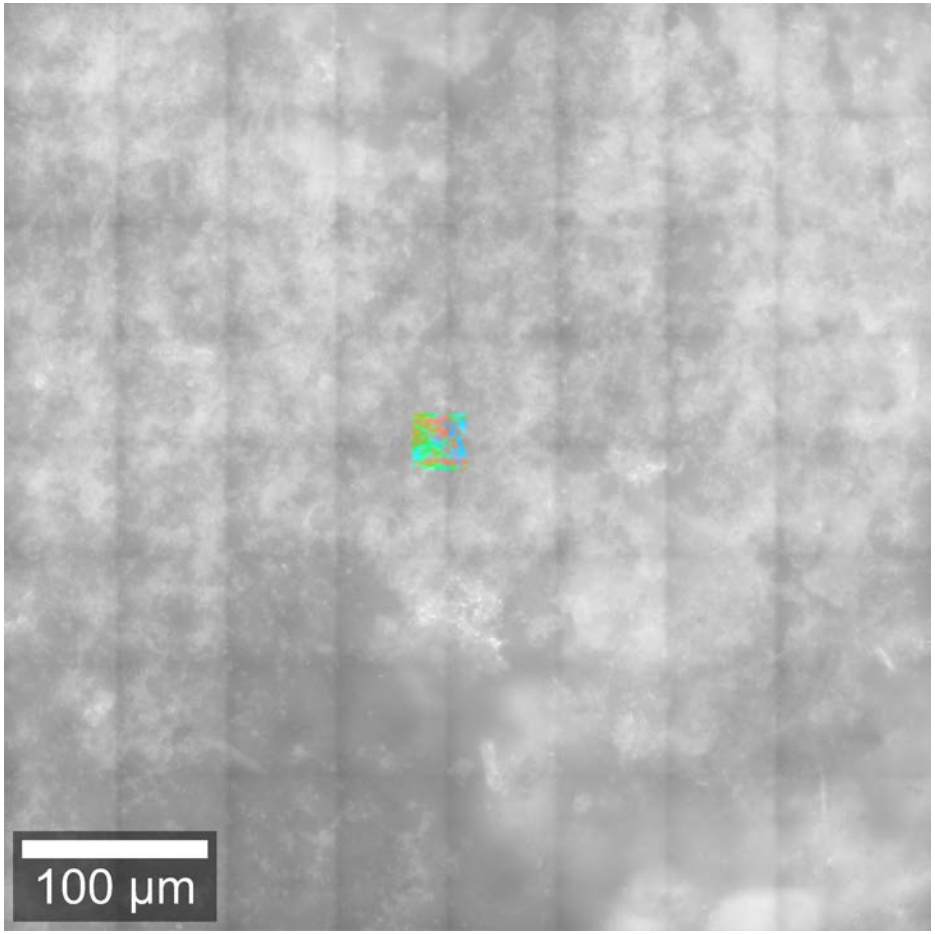
In its circulatory language, these models operate as a gesture toward a financial economy gaining material register as extractive hotspots around the world. The tank's tubes and pumps give form to a circulatory system of positions taken on positions, and reference an economy of increasing abstraction, built atop sediments that carry a history of violence and dispossession.

The project's use of hydrologic media as metaphor serves to echo a lineage of

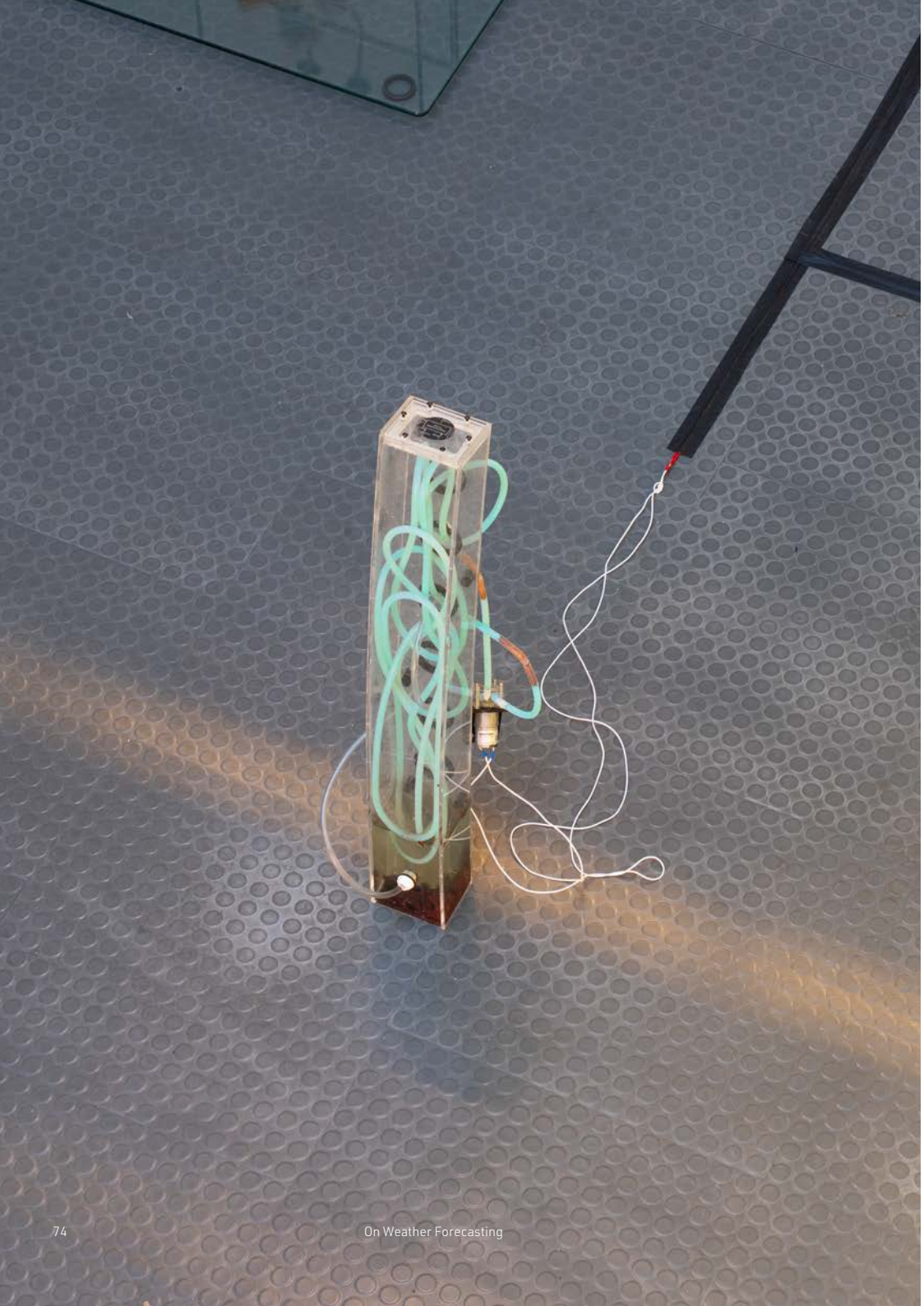
[Figure 4] Cemented copper and iron in the bottom of Accumulator 01.



[Figure 5] Petridish sample of cement copper from of Accumulator 01.



[Figure 6] RAMAN spectrograph of wastewater sample from Superfund Site in Woburn MA taken by the artist. This method of imaging maps the various chemical compositions of sample material. RAMAN spectroscopy is used in a variety of fields, from the characterization of paint in art conservation, to the search heavy metals in environmental samples.



economic models that use scaled thermodynamic and hydrologic mechanical systems as metaphors for the flow of capital. In particular, the works in Tailings reference the Phillips Machine [Figure 3], also known as the MONIAC, a nod to the ENIAC digital computer of the same year (the ENIAC was the first device to digitally compute a weather forecast). The machine was conceived by Bill Phillips, a New Zealand-born engineer turned economist who designed the machine to demonstrate the circular flow of money within the economy. Income, taxation, savings rate, consumption curves were all encoded by some physical mechanism: a valve, pump, tank, or channel. The command of environmental media: water, but also air and electricity, exemplifies the modern fantasy of keynesian levers, but also its orientation to the orchestration of environmental flows.

The Phillips Machine extended environmental control as metaphor for the regulation of money markets by a central bank, and in doing so demonstrated the modern perspective that these environmental media can and should be orchestrated and governed in service of economic growth. The machine was watertight enough to make calculations to around two percent of what mathematical models of the economy understood to be a ground truth. Two MONIACS could be attached together to model international trade by plugging the "export" pipe of one into the "import" pipe of another. The modularity of the Phillips Machine as a programmable, extensible model demonstrated capitalism's ambition for the planetary in the post-war period.

In Tailing, the Accumulator Tanks are positioned as a kind of Phillips Machine. The hydrologic metaphor that Phillips and economists used (and still use) is applied to the flows of financial capitalism whose abstraction has always been underwritten by and infrastructurally composed of, the minerals of industrial extraction. Here, the Accumulator tanks are descriptive through sedimentary accumulation, chemical change, and loops rather than hydrodynamic control. To the extent hydrodynamic control is on display, it is to emphasize absurdity rather than command. In Tailings the financial derivative is positioned alongside mine waste as seperate moments in the same metabolic model.

Folding Inward: Model Collapse

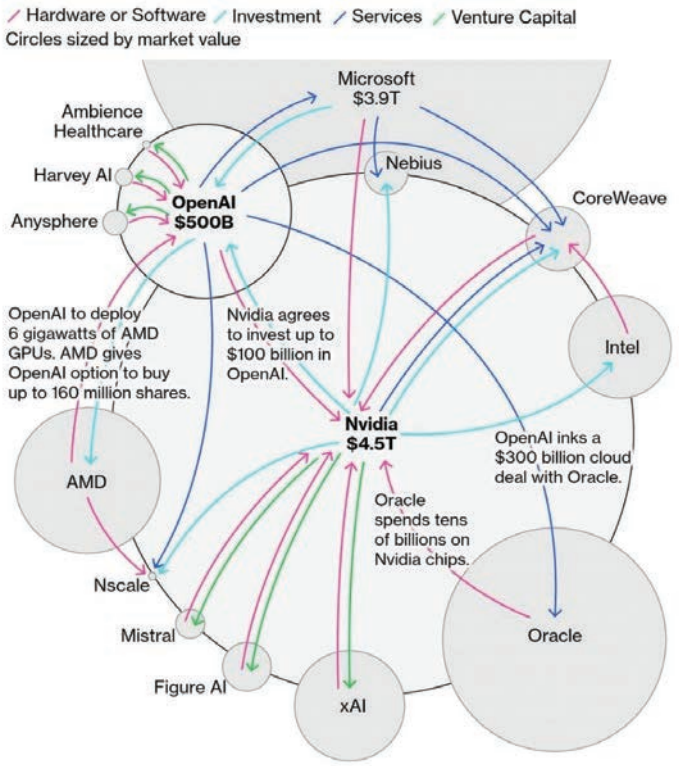
In the training of neural networks, AI companies have ingested virtually all of the internet. In the case of AI weather forecasting models this training data is composed of vast amounts of available weather observations, as well as the

historical predictions of other weather forecasts. ‘Organic’ data, that is, data accumulating in the world through human measurement and collection, is finite and has largely already been ingested, so in the training inputs for the next generation of models, labs are now turning to ‘synthetic’ data, or data that is generated by another model and used in training. This recycling of model outputs can improve the model at first, but risks a phenomenon that AI researchers have termed ‘model collapse:’ the threshold at which neural networks experience a sort of statistical atrophy after consuming too many synthetic inputs. ’

Kate Crawford extends this phenomenon to the environmental and social systems that sustain this infrastructure [cite Kate Crawford]. As these abstractions nest and accumulate, things degrades slowly at first, then all at once in a kind of ‘tipping-point’ not dissimilar from certain thresholds of planetary system collapse under various global warming scenarios. As the metabolic feedback loops of our world grow tighter, ‘uncycled material’ is increasingly returned to work in service of the device that produced it: mine tailings are re-mined for material to build data centers and synthetic weather data is generated to predict the weather.

What binds and accelerates this folding inward is a financial model bent on growth for its own sake. A diagram circulated widely in 2023 and 2024 charting the cross-ownership web of the AI industry: Microsoft invested in OpenAI, which licensed models to Azure, which ran on Nvidia hardware, in which Microsoft held equity, alongside a constellation of venture funds each cross-invested in the next layer of the stack. The diagram was striking not for its complexity but for its circularity — capital at every node referencing capital at every other node, a closed loop of mutual speculation with no terminal consumer at the end.

This financialization of the tech sector illustrates the fundemental logic of financial capitalism, where such synthetic feedback loops have been structurally embedded for decades. Derivative contracts reference other derivatives, index funds reshape the prices of the assets they track, and algorithmic systems like the Black-Scholes algorithm generate the order-flow patterns it is trained to exploit. The position, taken on a position, taken on a position is the operating logic of self-referential markets: “when one tries to protect oneself, and thus perhaps feels safe, one makes the future even more unpredictable.”[1]



[Figure 7] A now famous diagram from Bloomberg News showing the circular investment and exposure of AI investment.

Financial capitalism has developed instruments for extracting value not from stable underlying assets but from movement itself, from the spread between two prices, two forecasts, two assessments of the same future. It does not need the system to be healthy. It needs something to move, and it needs to know before everyone else that it will. The 2008 financial crisis was a model collapse of this kind: the loop consumed its own synthetic outputs until it failed, and then the state absorbed the loss and the system resumed, recapitalized and largely unreformed. What followed in the post-recession years was not a reckoning

with financial capital, but an expansion of the same logic into new instruments: high frequency trading, prediction markets, cryptocurrency speculation, big data fueled investment, each innovation a new version of abstraction from its referant. The climate crisis is not a problem for this system. The forecasting apparatus that measures atmospheric deterioration is now owned by the same capital that trades on it. All that matters to capital is that something moves.

Footnotes

Esposito, Elena. The Future of Futures: The Time of Money in Financing and Society. Translated by Elena Esposito with Andrew K. Whitehead, Edward Elgar, 2011, p. 107.

Phenomena

Long Time

This section traces how the privatized forecast registers materially at long timescales: in catastrophe modeling, climate risk pricing, and the withdrawal of insurance capital from vulnerable geographies. It argues that proprietary climate forecasts organize the silent reallocation of risk decades before the public can perceive or respond, producing a structural asymmetry whose costs are absorbed by homeowners, municipalities, and ultimately the state. The California wildfire insurance collapse is taken as the developed case, with Florida's property insurance market as a parallel instance.

Climate Redlining

The clearest contemporary illustration of long-time forecasting asymmetry is climate redlining, sometimes called bluelining: the systematic withdrawal of insurance, mortgage capital, and investment from geographies that proprietary climate forecasts have identified as high-risk. The mechanism operates as a chain. Climate forecasts at parcel-level resolution generate long-term projections of fire, flood, heat, and wind exposure. Those forecasts feed catastrophe models that translate physical risk into expected loss. The loss estimates determine insurance pricing and availability, which determine mortgage eligibility, which determine property values, tax bases, and the financial viability of communities. At every stage the forecast is the operative document. At every stage it is held privately.

The infrastructure producing these forecasts is a recent assemblage of climate analytics firms operating at spatial and temporal resolutions that exceed public capacity. First Street Foundation produces parcel-level risk scores for flood, fire, wind, heat, and air quality across the entire United States. Jupiter Intelligence operates at 90-meter resolution for financial institutions assessing physical climate risk at the level of individual assets.[1] Moody's, S&P Global, and CoreLogic have acquired climate modeling capacity directly. These forecasts are now integrated into the operations of Fannie Mae, major insurers including Allstate and Zurich, real estate platforms including Zillow, and the Federal Housing Finance Agency.[2] The federal government's own forecasting institutions, NOAA and the National Weather Service, do not produce equivalent risk indices at this resolution or with this integration into financial decision-making.

The asymmetry this produces is structural. A homeowner in a fire-prone Sierra foothills zip code does not have access to the climate forecast that her insurer is using to non-renew her policy. The municipal government does not have access to the climate forecast that the credit rating agency is using to downgrade its bonds. The mortgage applicant does not have access to the climate forecast that the lender is using to deny the loan. The forecast that organizes whether a community can be insured, financed, or sold operates above the household and above the state, and its conclusions arrive as decisions that have already been made.

The California wildfire insurance collapse is one instance of this pattern.

Following the 2017 and 2018 fire seasons, climate forecasts of fire weather frequency and dry season length recalibrated upward across large portions of the state. Catastrophe models translated those forecasts into elevated loss probabilities. Insurers responded. Non-renewals jumped 42 percent in the immediate aftermath, reaching nearly 235,000 households.[3] In May 2023, State Farm announced it would stop accepting new property insurance applications in California, citing "rapidly growing catastrophe exposure" and a challenging reinsurance market.[4] Other major carriers followed. The FAIR Plan, California's insurer of last resort, ballooned as homeowners with no other options were forced into limited coverage.

What appears as a corporate decision is the operationalization of a forecast. The climate models that drove the recalibration are not publicly accessible at the resolution and integration that capital uses. The state insurance commissioner has been responding to a market that had already repriced itself on forecasting infrastructure it does not have. California's Sustainable Insurance Strategy, finalized in 2024, allows insurers to use forward-looking catastrophe models in rate-setting in exchange for commitments to write in high-risk zones.[5] The arrangement concedes the underlying condition: the climate forecast that organizes the insurability of a region is now produced by capital, on a timescale and at a resolution that public institutions cannot match.

The political weight of the term redlining is appropriate to what the mechanism produces. Historical redlining used racial and economic criteria to systematically deny mortgages and insurance to particular geographies. Climate redlining uses proprietary climate forecasts. The continuity is structural: a privately held instrument of risk classification determines which communities have access to capital and which do not, and the affected communities have no access to the instrument. Federal Reserve Chair Jerome Powell put the trajectory plainly in February 2025 testimony before the Senate Banking Committee: "If you fast forward 10 or 15 years, there are going to be regions of the country where you can't get a mortgage. There won't be ATMs. You know, the banks won't have branches and things like that."[6] What Powell described is the long-time register of the privatized forecast operating at its logical conclusion. The model arrives first, the capital exits next, the community discovers the forecast through its consequences.

The forecasts themselves are not stable, which sharpens the political stakes. A comparison by the climate research nonprofit CarbonPlan of two leading pro-

prietary fire risk models, Jupiter Intelligence and XDI, found that the models agreed on only 12 percent of California locations where fire risk would increase this century.[7] Coastal flooding projections for New York City in 2100 produced only 21 percent agreement between the same two models.[8] The "forecast" that organizes insurability is not a single authoritative document but a set of competing proprietary instruments whose internal logic, training data, and assumptions are not disclosed. Capital chooses among them. The communities affected by their outputs cannot.

Footnotes

[1] Jupiter Intelligence, "Climate Metrics for Mortgage Risk," accessed via jupiterintel.com.

[2] Ryan Kingsley, "Zillow, First Street Bring Climate Risk to Borrowers," National Mortgage Professional, September 26, 2024; Diana Olick, "Mortgage Giant Fannie Mae Tackles Climate Risk," CNBC, March 20, 2023.

[3] Ben Christopher et al., "State Farm Won't Sell New Home Insurance in California," CalMatters, May 19, 2023.

[4] State Farm General Insurance Company, "California New Business Update," May 26, 2023.

[5] California Department of Insurance, Sustainable Insurance Strategy, finalized 2024.

[6] Jerome Powell, testimony before the Senate Banking Committee, February 2025, quoted in Shena Ashley and Sara McTarnaghan, "Lessons from Redlining: How We Can Prevent Climate-Driven Insurance Discrimination," Shelterforce, October 14, 2025.

[7] Eric Roston, "Is Your Home at Risk from Climate Change? It Depends on the Data Source," Bloomberg Green, August 12, 2024

Plots, Grids, Models

The various works in Plots, Grids, Models (2023-2025) collage watercolor rendering techniques – machine-plotting, hand-painting, lifting, washing, masking – as layers in the grid. The work references digital imagery, maps, contemplative renderings of ecologic space, and the woven architecture of the frame.

Wielding references to cartographic projection, symbology, and data, the works collages these structural scaffolds with representations of a site's light, flow, and texture.

The discipline of painting has a long lineage of modeling landscape. Models, (paintings) are imbued with the bias of their maker, their history and social context. I am interested in reasserting the discipline of painting as a form of model-making and as a resurgent device for reflecting the measured and automated methods of understanding and controlling landscape today.

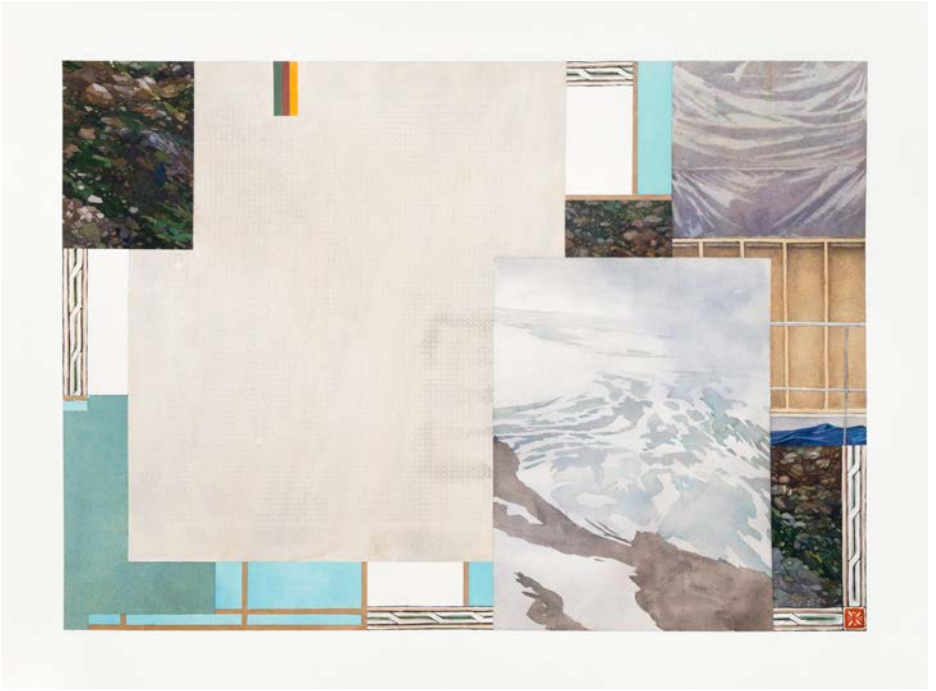
These (re)constructions of place oscillate between art historical references of painting's central role in the governance of territory: from the geological surveys of the American West in the 1870s that brought painters and cartographers into the field together for surveys [1], to iconographic flourishs of manustripts that mapped cosmologic infrastructure and weather [2]. The genre of landscape painting was a device by which land became knowable and available for classification and governance. In this sense the history of painting, landscape architecture, geography, and ecology are deeply entangled. Painting served very directly as models of out there space, but also operated with its own lineage and logic.

Perhaps the artifact that best holds this schizophrenic condition of painting is that of the grid. This loaded spatial device encodes a set of claims about space, flatness, and the relationship between the pictorial surface and the world.

Grids

In her text Grids, Rosalind Krauss traces the pre-modern role of the grid as a scientific device for constructing space, perspective, and color [3]. As modernist rationalism put forth the grid as its emblem for ordering the real, it simultaneously aqcuired a symbolic and pseudo-spiritual quality in art and culture.

By its very abstraction, the grid conveyed one of the basic laws of knowledge-



Flow Field - Plot 6
30 x 22 inches
watercolor and gouache on paper
2023

-the seperation of the perceptual screen from that of the "real" world... [the grid] became an emblem of infrastuctural vision. The more [neo-impressionist painting] applied these lessons, the more "abstract" their art became, so that as the critic Felix Feneon observed of the work of Seurat, science began to yeild its opposite, which is symbolism.

Krauss identifies in the grid a kind of double movement: centripetal, collapsing inward onto the surface and insisting on its own logic; and centrifugal, extending outward infinately in the world. It is this outward extension, the grid's claim to totality, that culture absorbed and exported back into the world as naturalized worldview. In this sense, science lent culture the grid, and culture returned it charged with spiritual authority.

Figure 1. Survey markings of parcel to be logged near artist's home in Deming Washington in 2023.

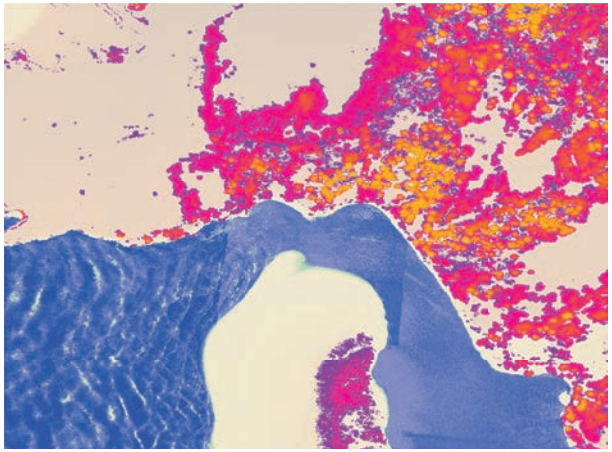


Figure 2. Artist characterization of the old growth forest at Cascade Head, Oregon from LIDAR data.

Bell Creek - Plot 5
30 x 22 inches
watercolor on paper
2022

Krauss observes that the centrifugal grid extends into the third dimension. Here the two-dimensional grid becomes a lattice. Citing Sol LeWitt's modular structures, the architectural projects of de Stijl, the spatial systems of Rietveld and Vantongerloo, the decorative grids of Frank Lloyd Wright: the grid leaves the canvas and becomes a theoretical model of architectural space in general, of which any built fragment is one realization.

Since Krauss wrote Grids in 1979, the financialization of everyday life [4] has extended the ubiquity of the grid firmly into a fourth dimension. The invention of the financial index, the futures contract, and the derivative instrument lay coordinates out into the future. Volatility, weather, credit risk, and commodity price are measured, mapped, and valued as positions in a temporal lattice. Where the cadastral map divided land for ownership, the proliferation of

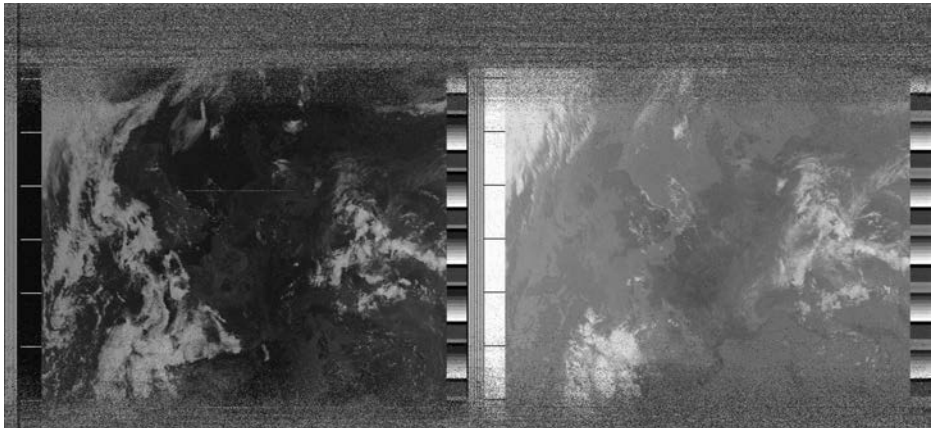
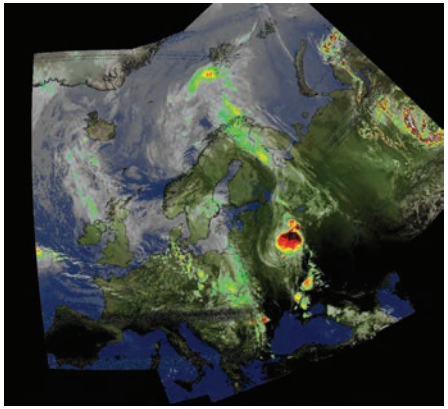


Figure 3. Image scraped from the Russian Meteor 14 satellite.



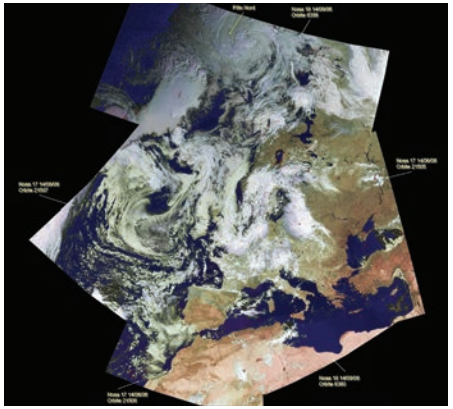


Figure 4. A now famous diagram from Bloomberg News showing the circular investment and exposure of AI investment.

Model 8
21 x 6 inches
watercolor and gouache on paper,
mounted on wood panel
2024

financial products and space divides time for speculation, marking the grid's movement into temporality.

Of courrse, the temporal grid has been a significant device for science since before the 19th Century. Examples of its use can be found in the cameral sciences of German forestry that were exported to the United States as a form of forest management, or in the nineteenth-century entanglement of meteorology and maritime risk that produced the first systematic weather forecasts. However, what marks this particularly recent shift in the dominance of the grid is the proliferation of financial capitalism which, by its nature, has set out to create a totalizing temporal index of planetary uncertainty.

This recent expansion in the authority of the grid is one of resolution and scope. Proprietary catastrophe models compartmentalize the planet's atmospheric future at parcel-level resolution, projecting hurricane, wildfire, and

flood risk decades forward as actuarial coordinates. These risk indices take some uncertain dimension of the changing planet and render it actionable in the present [5].

At each step the grid carries its earlier authority forward. The 2D grid made certain claims about the knowablity of matter. The 3D lattice claimed the same of architectural space. The fourth dimensional grid claims it of time.

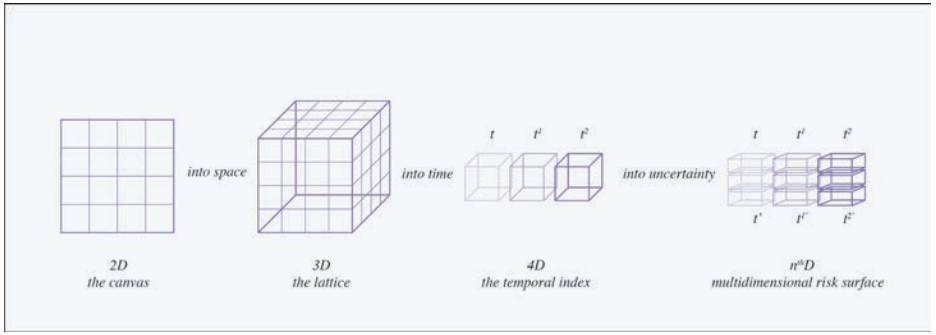
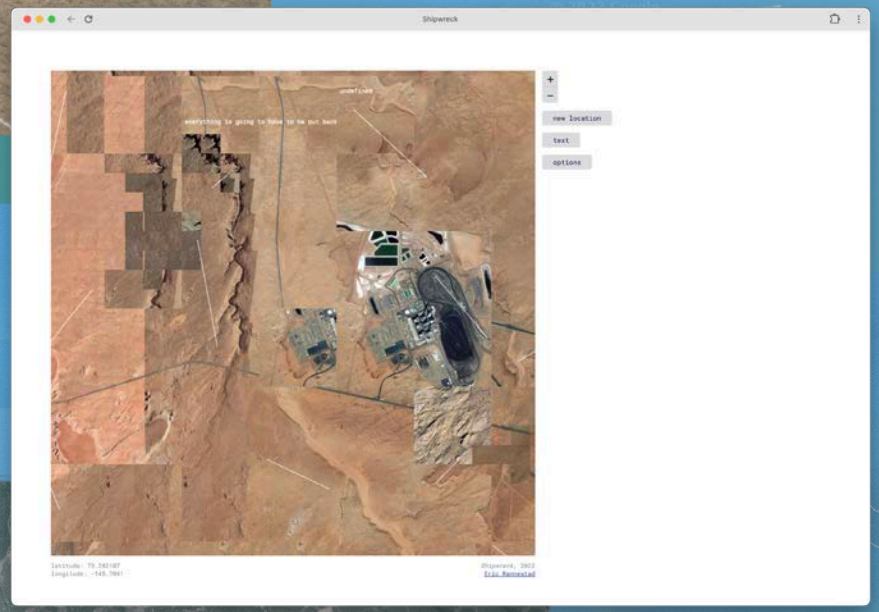
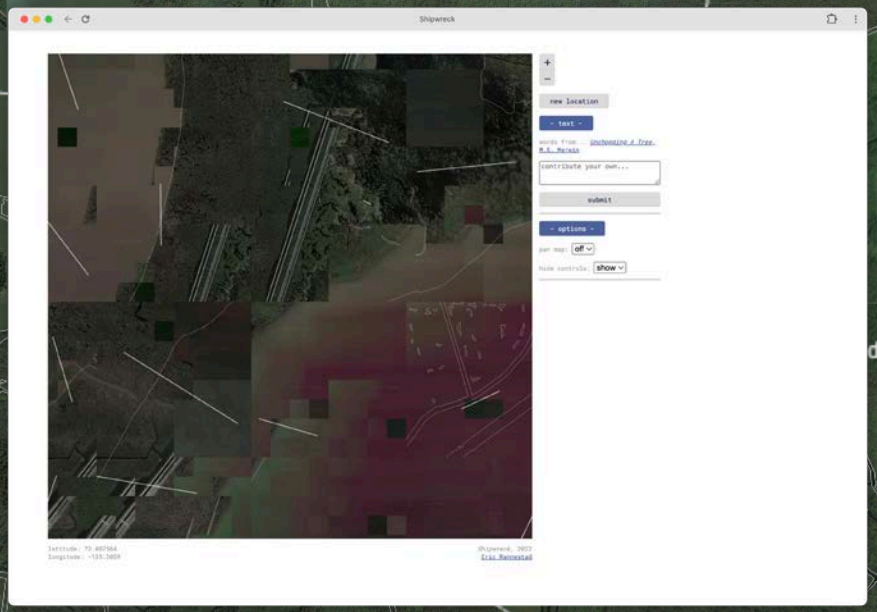


Figure 4. The proliferation of the grid into nth order dimensions.

Shipwreck 2023
Web Mapping Application



Shipwreck 2023
Web Mapping Application



Shipwreck 2023
Web Mapping Application

Shipwreck 2023
Web Mapping Application

Footnotes

[1] Kinsey, Joni L. Thomas Moran and the Surveying of the American West. Smithsonian Institution Press, 1992.

[2] Truettner, William H., ed. The West as America: Reinterpreting Images of the Frontier, 1820–1920. Smithsonian Institution Press, 1991.

[3] Krauss, Rosalind. “Grids.” The Originality of the Avant-Garde and Other Modernist Myths. MIT Press, 1985, pp. 8–22.

[4] Martin, Randy. Financialization of Daily Life. Temple University Press, 2002.

[5] Esposito, Elena. The Future of Futures: The Time of Money in Financing and Society. Translated by Elena Esposito with Andrew K. Whitehead, Edward Elgar, 2011, p. 107.

[6] Bois, Yve-Alain. Painting as Model. MIT Press, 1990.

Phenomena

Time Control

This section traces how the privatized forecast registers as proposals for technical intervention in the atmosphere itself. Direct air capture and stratospheric aerosol injection are taken as the operational and imagined cases. It argues that both interventions are downstream of the forecasting apparatus that defines their operative variables, and that what falls outside the model's space of consideration falls outside the proposals' as well.

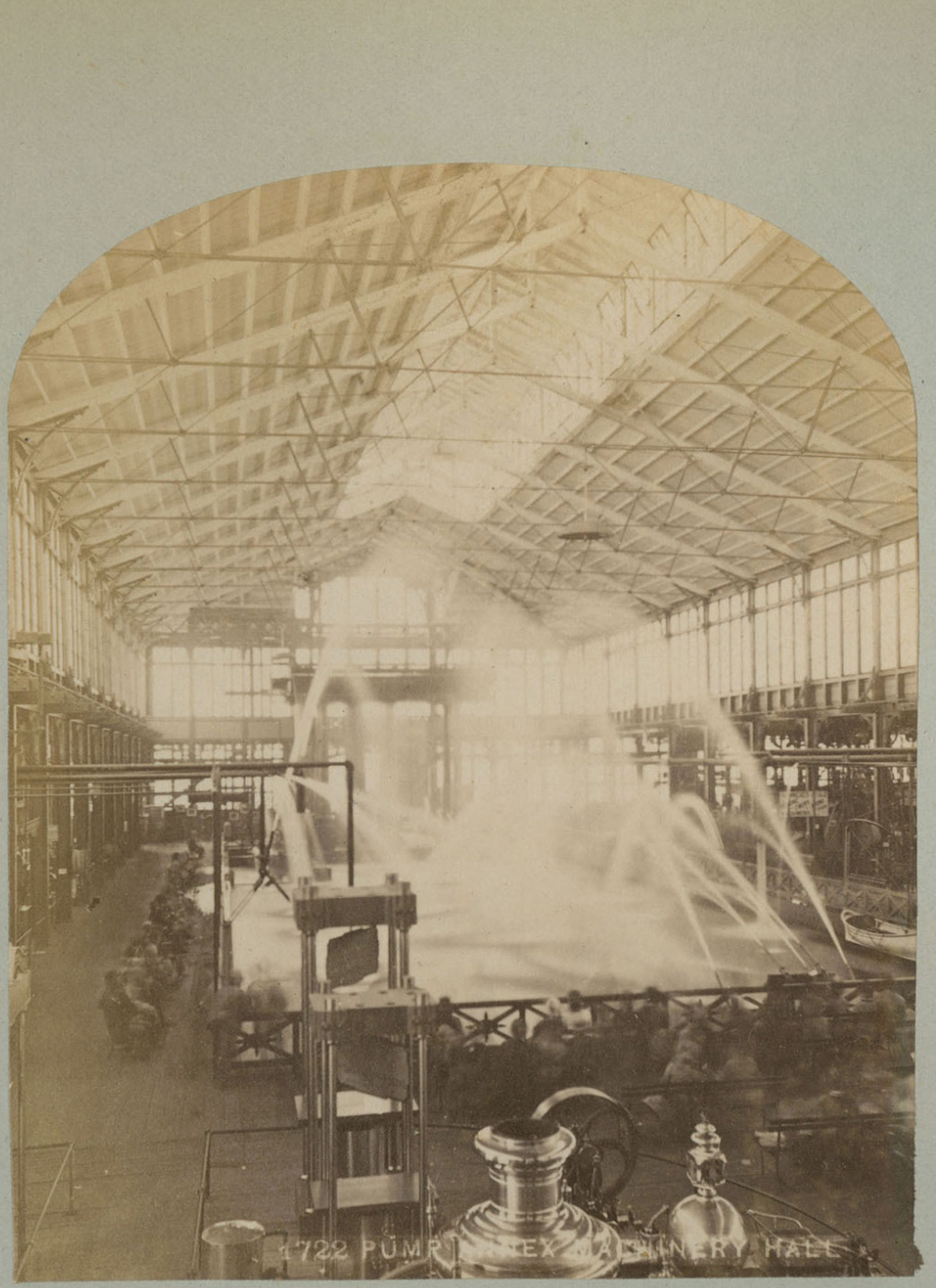
Understood as a world-making device that produces the atmosphere as a governable object, the forecasting apparatus generates a third register of effects beyond the financial extraction described in the previous sections. Where short-time and long-time asymmetries concern the extraction of value from gaps between proprietary and public atmospheric knowledge, this section concerns what happens when the apparatus turns from prediction to intervention. The model that began as a representation of atmospheric behavior becomes the surface on which atmospheric futures are negotiated. Proposals to manage those futures arrive as technical operations on the model's variables: aerosol injection adjusts radiative forcing, direct air capture adjusts atmospheric carbon concentration.

Foucault's argument that visibility is the primary instrument of governance is operative here. The atmosphere that can be governed is the atmosphere the apparatus has rendered visible. Proposals to address the climate crisis become legible only within the projected space the apparatus constructs. Territories, timescales, and atmospheric phenomena outside that space fall outside the proposals' space of consideration. This is time control: the production of conditions under which atmospheric futures become objects of technical intervention, bounded by what the apparatus has made calculable.

Direct Air Capture

The Climeworks facility in Iceland represents the operational present of forecast-organized atmospheric intervention. Climeworks operates Orca, opened in 2021, and Mammoth, opened in 2024, both partnered with the Icelandic firm CarbFix, which injects captured carbon dioxide into basalt formations where it mineralizes within approximately two years.1 The facilities function. Carbon is removed from the atmosphere.

The intervention's relationship to the forecast that justifies it is what makes it legible as time control. Orca was designed to capture approximately 4,000 tons of CO2 per year. Mammoth scales that capacity by roughly an order of magnitude. Global annual emissions exceed 40 billion tons. The facility's justification rests on the projection that the technology will scale to match the gigatons of negative emissions that IPCC scenarios specify as necessary to remain below temperature thresholds. Without those scenarios, the facility has no business case. Capital flowing into direct air capture, from corporate offset purchases to the US Department of Energy's Regional Direct Air Capture Hubs, is organized



[Figure 2] The pump annex of the 1876 US Centennial Exhibition

by forecast scenarios produced through the same forecasting infrastructure whose privatization has been the subject of this essay.

aThe Stratospheric Controlled Perturbation Experiment (SCoPEx) was a Harvard research project led by David Keith and Frank Keutsch to test the dispersion of small quantities of calcium carbonate particles in the upper atmosphere. SCoPEx was the proposed first instrumental step toward solar radiation management at planetary scale. The experiment was scheduled to launch from Sweden in 2021, postponed following objections from the Saami Council and Swedish environmental organizations, and formally cancelled in 2024.2

The justification for stratospheric aerosol injection rests on climate models projecting that global mean temperature will exceed thresholds beyond which conventional mitigation cannot deliver acceptable outcomes. The intervention is engineered to operate on a single variable in those models: incoming solar radiation. Reducing that variable by 1 to 2 percent, the models suggest, would produce a corresponding reduction in mean surface temperature comparable to the cooling observed after Mount Pinatubo in 1991.

What the models do not optimize for, the proposal does not address. Regional precipitation patterns under aerosol forcing diverge from regional precipitation patterns under greenhouse forcing, with documented potential for monsoon disruption across South Asia and the Sahel. The termination shock problem, in which any cessation of injection would produce rapid temperature rebound, commits the intervention to indefinite continuation. The Saami Council's objection to SCoPEx, framed in terms of indigenous relations to atmosphere, weather, and land, did not contest the experiment's science. It contested the apparatus that determined which considerations could be admitted as relevant.

Direct air capture and stratospheric aerosol injection operate at different scales and temporal horizons, but they share a logic. Each is engineered to operate on a variable the climate model recognizes. Each presupposes the model as the relevant description of the atmosphere. Each is funded, planned, and justified through the forecasting infrastructure whose privatization has been the subject of this essay. The technical operations they propose are downstream of the apparatus that defined the operative variables in the first place. What is foreclosed by accepting the model as the surface on which atmospheric futures are negotiated is what falls outside the model's space of consideration.

[Figure 2] Operation Stormfury and Hurricane Esther

Footnotes

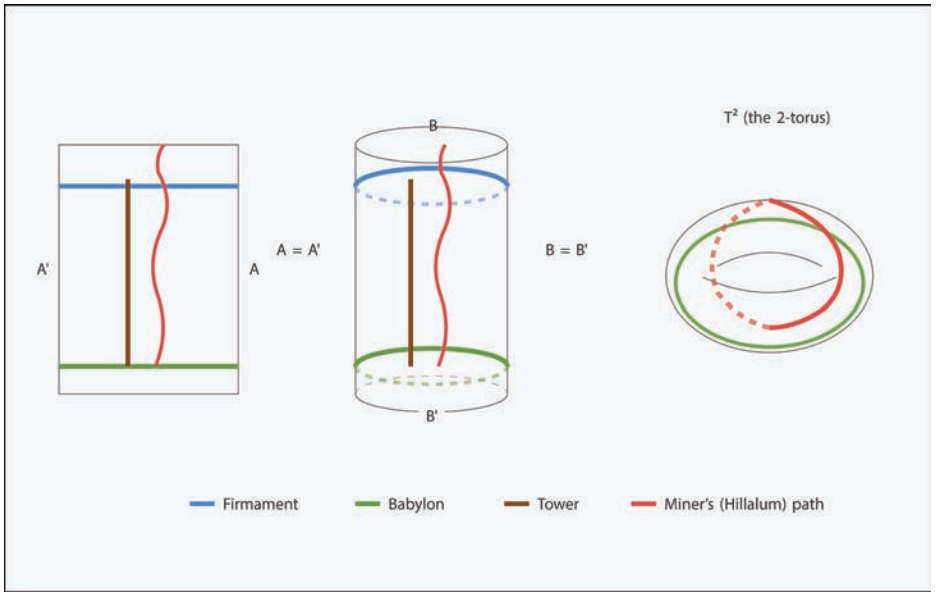
[1] Elizabeth Kolbert, Under a White Sky: The Nature of the Future (New York: Crown, 2021).

[2] Kolbert, Under a White Sky. On the cancellation, see Harvard Solar Geoengineering Research Program, "SCoPEx Project Update," March 2024.

Firmaments

In Ted Chiang's short story "Tower of Babylon," miners climb a tower built to breach the firmament in the sky (a dome that suspends the ocean of heaven above the earth) in order to enter this heavenly vault. Upon breaking through, they are carried by floodwaters through the rock until they emerge back on earth. The world, it turns out, is shaped like a cylindrical seal: heaven and earth do not face each other across an infinite distance, but fold back and touch, so that the longest journey upward returns you to where you started. The miners do not find God on the other side of the vault. They find their starting ground, and one that is eorganized in pursuit of their journey.

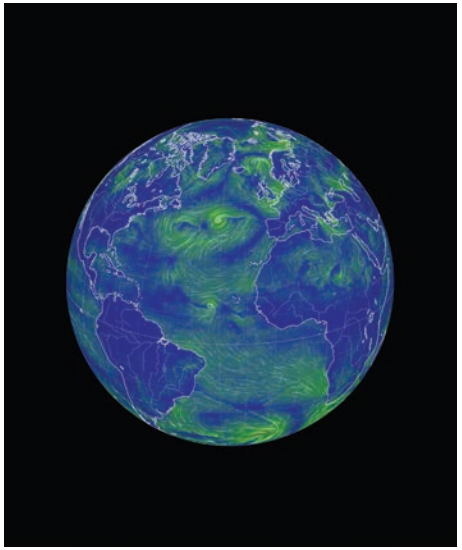
What the story describes is the governing function of the topological model: the flat-tablet cosmology, heaven above and earth below with the firmament between, organized centuries of labor and material. The firmament was not



Above: [Figure 1] The diagram traces the topology in three stages: the flat cosmology with the Tower rising from Babylon through the firmament, the cylinder produced by gluing the east-west edges, and the torus produced by gluing top to bottom. The miner's path appears in each stage as the same trajectory – what reads as upward escape on the flat tablet becomes experienced as a closed loop.

Right: Accumulator Tank 04 (detail)
Acrylic, Bentonite Clay, Steel, Silicone, Diaphragm Pump, Air Compressor.
9 x 8 x 5 feet
2026

[Figure 2] Pre-scientific cosmologic diagram indicating social hierachies in relation to weather and ground.



[Figure 3] pointcloud.garden
website
2020, http://www.pointcloud.garden/

A digital twin is a digital model of an intended or actual real-world physical product, system, or process (a physical twin) that serves as the effectively indistinguishable digital counterpart of it for practical purposes, such as simulation, integration, testing, monitoring, and maintenance.

wrong in any simple sense; it was real, but the space the model projected onto the world was not the space the world actually occupied, and all the infrastructure built to operate within that projected space could not reach beyond it.

I am very interested in the technical hubris of Chiang's story and its positioning of the technical utopia and the cosmic model. Chiang describes a cosmology so total that it cannot perceive what it excludes. The firmament was the absolute edge of the known world, and breaching it returned the miners to where they started. "By this construction, [the miner's] work was indicated, and [the miner's] work was concealed."

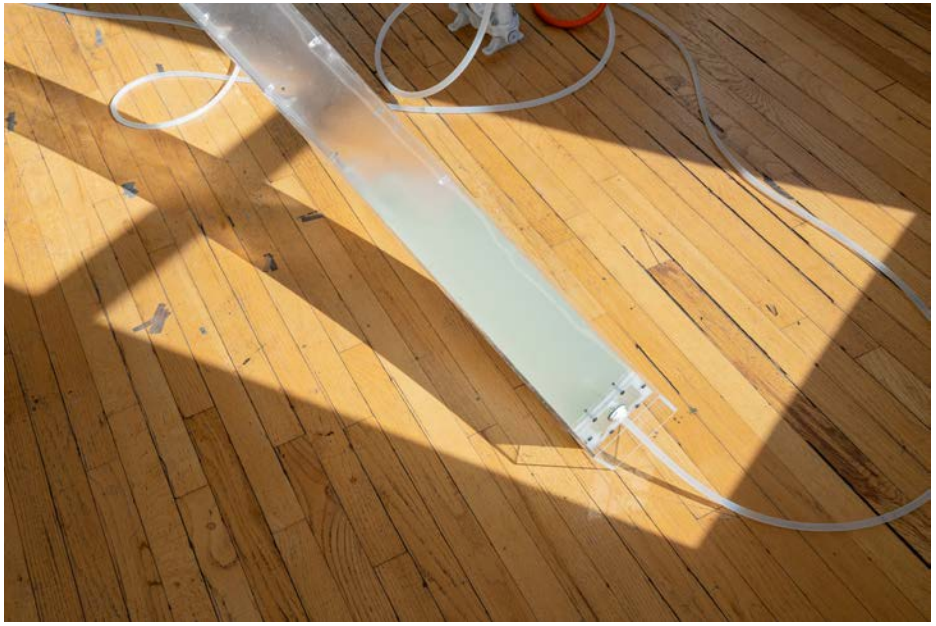
What falls outside the projected space cannot be seen from inside the model and cannot be corrected through its internal diagram. It's exclusion is a condition of the model's coherence. The technical patch cannot account for what it excludes without ceasing to be a patch.

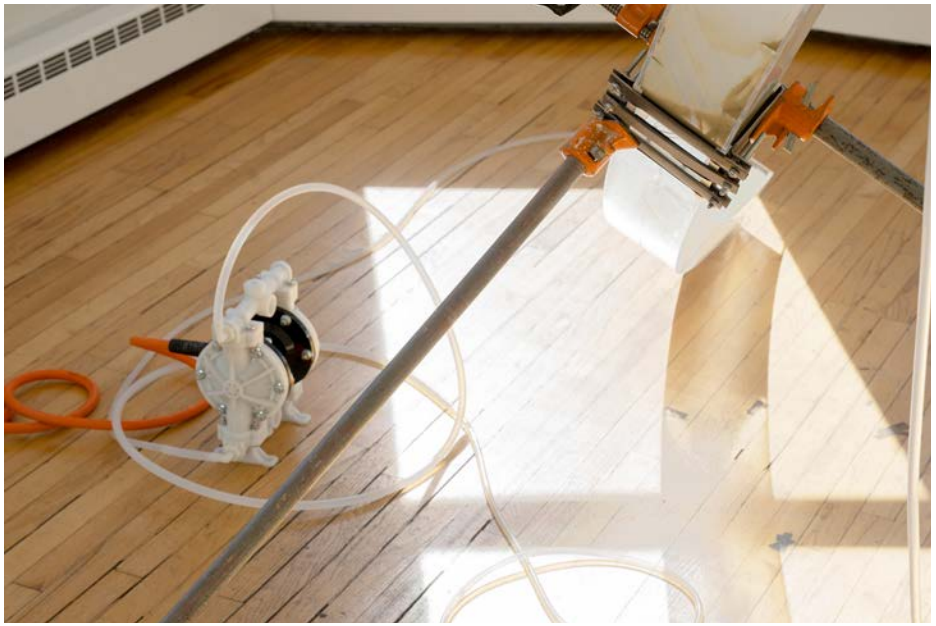
Accumulator Tank 04
Acrylic, Bentonite Clay, Steel, Silicone, Diaphragm Pump, Air Compressor.
9 x 8 x 5 feet
2026

The planetary systems model that orchestrates various forms of atmospheric governance inhabits this same loop. Proposals for interventions in atmosphere, enabled by the forecast apparatus and its totalizing, knowable simulation of the planetary, has generated proposals in its image. The vertical farm, the carbon offset, the cloud seeding initiative, and solar geoengineering proposal each occupy a technical role in a system oriented at this projection of space.

The following sculptures are part of a series of work that reimagines cosmological structures of the past and positions them as technocratic systems of atmospheric governance. The work conflates pre-scientific cosmological structures with utopian ideals of planetary control and forecasting. The planetary apparatus of 'green capital' and its measured and choreographed atmospheres merge with the fantastical infrastructure of the firmament.

In Firmament Arch and Firmament Truss, the curved backbone of each work





houses a network of tanks, tubes, pumps, and nozzles that create an aeroponic growing environment. Here, domesticated plants grow in irregular and confined spaces with minimal water waste or reliance on natural light.

I am interested in positioning certain utopian aesthetics of 'the green': the plant wall, the curved facade, and lightness of its materials, and setting it off-kilter, off-axis. In the work I try to expose a certain precarity to these objects and their reference. The economic and technical systems of green capital are something I have looked to as logics to fragment and arrange as kinetic gestures.

Such proposals for atmospheric governance and manipulation have proliferated with the climate crisis, all along ideological lines, each with their own utopian ideal. The proposals from the market-environmentalist left describe technical patches to atmospheric conditions and the corresponding crisis in energy, food production, or extreme weather. The success of these patches are predicated on where one draws the frame of assessment in time and space.

The vertical farm, assessed within the frame of a single unit's water usage and food miles, is a technical feat of near-zero runoff, reduced pesticide use, and dense production. Extend the frame to include the energy demands of these facilities, the real estate logic that the plant wall reliably precedes, and the industrial agriculture system that subsidizes fuel, meat, monocropped operations of corporate America and the miracle recomposes. The climate crisis to which this food precarity is inextricably linked, occupies a similar solution-space in the form of carbon offsets which tout a certain equilibrium by ledger. At this point, the fallacy of the balance sheet frame is well documented as both a financialized abstraction [cite] and a spatial inequity dictated by power [cite]. Costs are displaced onto other bodies, territories, and timescales but the ledger balances (though this is not even true). In each case, the patch works only for as long as, and only for whom, the frame holds.

What connects the pre-scientific firmament to the dream of the planetary thermostat is a shared cosmological structure: both project a model of bounded, legible space onto a world that exceeds it.

Top and Bottom: Accumulator Tank 04 (detail)
Acrylic, Bentonite Clay, Steel, Silicone, Diaphragm Pump, Air Compressor.
9 x 8 x 5 feet
2026

Firmament Truss
OSB panel, plywood, aquaresin, fiberglass, steel, aeroponic growing system
14x 5 x 6 feet
2023

Firmament Truss (detail)
OSB panel, plywood, aquaresin, fiberglass, steel, aeroponic growing system
14x 5 x 6 feet
2023

Firmament Arch
plywood, steel rails,enamel, aeroponic growing system
10x 7 x 7 feet
2021

Firmament Arch (detail)
plywood, steel rails,enamel, aeroponic growing system
10x 7 x 7 feet
2021

Phenomena

Time Dissociation

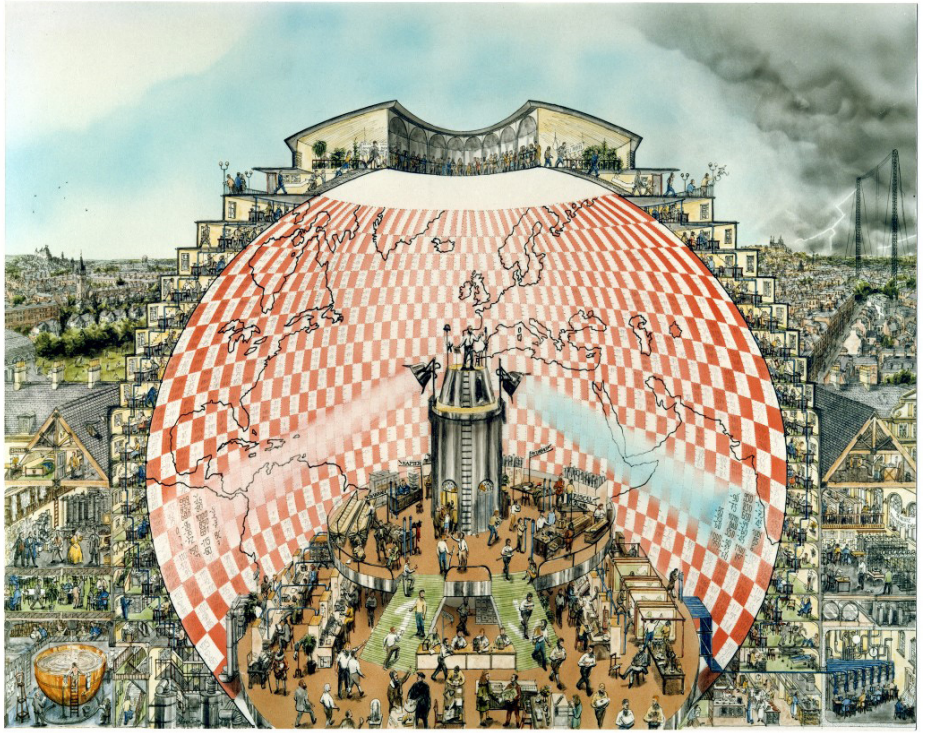
The forecast registers in the phenomonology of the human lived experience, namely as a changed relationship to time and environment. Beyond the forecast's very obvious role of dictating the future of weather and climate as future atmospheric experience, its more diffuse but equally important entanglement with economy propagate through to individual lived experience as well. Some of these registrations are evidenced in the previous chapters as digital infrastructures of speculation, the movement of capital around long-term trends that evade individual agency, and proposals to patch leaks in our models of environmental control. In this economy of relations to weather, the human is a consumer of its financialized time and of ground reorganized in its image. Agency is returned to the subject only as a participation in that system.

The etymology of the apparatus has its attachments to "the economy," specifically an economy born out of the ontological separation of being and praxis. Giorgio Agamben in his essay What is an Apparatus traces this device as a means of bifurcation: being was to be the domain of God, while economy, its modes of governance and constituent tools, was the domain of earthly administration. This separation between liveliness and subjectivity is enacted through the economy and its constituent apparatuses to produce subjects suffering from this schizophrenic condition. A separation from their nature. [1]

This ontological split, is produced by the forecast in that it mediates one's immediate, embodied encounter with atmospheric time, replacing lived weather with a managed projection of it. Weather is first an alert, insurance adjustment, or forecast cone; whereas embodied experience exists only relative to this frame. The subject's relation to uncertainty is returned to them only as a mode of consumption and blind dependency within that economy.

L.F. Richardson's Weather Prediction by Numerical Process (1922) is a canonical scientific paper in meteorology where he constructs a systematic mathematical method for predicting the weather and demonstrates its application by carrying out a trial forecast. [Figure 1] As a lofty aside in his paper, he ponders a forecast factory where workers simultaneously compute assigned cells of the global atmosphere, a central conductor coordinates their work with colored lights. [2]

> "Imagine a large hall like a theatre, except that the circles and galleries go right round through the space usually occupied by the stage. The walls of this chamber are painted to form a map of the globe.



[Figure 2] "Weather Forecasting Factory" by Stephen Conlin, 1986. Based on the description in Weather Prediction by Numerical Process, by L.F. Richardson, Cambridge University Press, 1922, and on advice from Prof. John Byrne, Trinity College Dublin. Image: ink and water colour, c. 50 x 38.5 cm. © Stephen Conlin 1986. All Rights Reserved ´. (Courtesy: Hendrik Hoffmann, School of Mathematics & Statistics, University College Dublin)

> The ceiling represents the north polar regions, England is in the gallery, the tropics in the upper circle, Australia on the dress circle and the antarctic in the pit. A myriad computers are at work upon the weather of the part of the map where each sits, but each computer attends only to one equation or part of an equation. The work of each region is coordinated by an official of higher rank... From the floor of the pit a tall pillar rises to half the height of the hall. It carries a large pulpit on its top. In this sits the man in charge of the whole theatre; he is surrounded by several assistants and messengers. One of his duties is to maintain a uniform speed of progress in all parts of the globe. In this respect he is like the conductor of an orchestra in which the instruments are slide-rules and calculating machines. But instead of waving a baton he turns a beam of rosy light upon any region that is running ahead of the rest, and a beam of blue light upon those who are behind."

Stephen Conlin's 1986 rendering [Figure 2] of Richardson's dream makes this planetary dream visible. The image reads less as a scientific proposal than as a governing system, though perhaps the two are not dissimilar.

The forecast factory functions as an apparatus in the Agambenian sense: a device that organizes human subjects in relation to a governing logic. Each worker is assigned a fragment of the planetary model, responsible for one equation or part of an equation, and relates to the atmosphere only through that fragment. Holistic atmospheric knowledge becomes the exclusive property of the center. The apparatus captures human praxis and reissues it as governance.

The conductor's colored lights make this visible at the level of lived experience. Rather than communicating meteorological data they communicate pace, synchronizing industrial time across the globe. The worker does not read the sky; they read the signal. The atmosphere recedes; what is being managed is the speed of the model relative to itself.

> "Four senior clerks in the central pulpit are collecting the future weather as fast as it is being computed, and despatching it by pneumatic carrier to a quiet room. There it will be coded and telephoned to the radio transmitting station. In another building are all the usual financial, correspondence and administrative offices. Outside are playing fields, houses, mountains and lakes, for it was thought that those who compute the weather should breathe of it freely."

The future weather moves immediately from computation into circuits of dissemination and commerce. The embodied outside, the playing fields and mountains and lakes, is a welfare provision. The factory's inside and the weather's outside are separated by design, and that separation is treated as efficient institutional organization rather than as a loss.

Richardson's concludes by conceding the arduous labor time and financial cost as the barrier to realizing such an apparatus. The race between computational time and atmospheric time has since been solved as a technical and economic constraint, and what and the structure that Richardson drew: the planetary model at the center, the human at the periphery, the weather outside has, in many ways, come to be.

> "Perhaps some day in the dim future it will be possible to advance the computations faster than the weather advances and at a cost less than the saving to mankind due to the information gained. But that is a dream."

Richardson identified labor time as the only remaining barrier to realizing the apparatus. The embodied relationship to weather had already been resolved out of the architecture. The race between computational time and atmospheric time has since been won as a technical and economic constraint, and the structure Richardson drew has, in many ways, come to be: the planetary model at the center, the human at the periphery, the weather outside.

What Richardson could not have anticipated was the degree to which the realization of that dream would be captured by private capital. The public forecast, organized around NOAA and the National Weather Service, retained something of Richardson's institutional ambition: a planetary apparatus in service of a public good, however imperfect. The privatized forecast inherits the architecture and redirects it. The pneumatic carrier dispatching future weather to the radio transmitting station has become a proprietary data pipeline; the financial offices in the neighboring building have moved to the center. The conductor no longer synchronizes computation for the benefit of mankind but for the extraction of temporal asymmetry across financial markets, insurance regimes, and capital flows.

The dissociation Richardson's architecture encoded was between the worker

and the weather outside. The factory's design resolved that separation as a matter of institutional efficiency: the weather was something you breathed freely after your shift. The dissociation the privatized forecast produces operates at a deeper register: between the subject and their own temporal condition. The future is something the apparatus manages on their behalf, and the subject participates in that management as consumer, as insured party, as the terminal point of a chain of abstraction that began with a reading of the atmosphere and ends as a financial instrument.

This is a different kind of separation than Richardson imagined. The factory worker at least knew they were inside a building, computing a model, with the weather waiting outside. The contemporary subject receives the future as if it were simply the future: as alert, forecast cone, premium adjustment, risk score. The apparatus has become ambient, and the managed projection of atmospheric time has become indistinguishable from atmospheric time itself. What is foreclosed is not access to the weather but the experience of uncertainty as one's own, as something to be lived with and navigated through rather than absorbed from a system designed to price and distribute it. The subject's relation to open time, to a future that has not yet been operationalized, contracts as the apparatus expands. Each extension of the forecast's reach into financial instruments, insurance regimes, and atmospheric intervention produces a corresponding narrowing of the temporal experience available to those who live within its frame.

Footnotes

[1] Giorgio Agamben, "What Is an Apparatus?" in What Is an Apparatus? and Other Essays, trans. David Kishik and Stefan Pedatella (Stanford: Stanford University Press, 2009).

[2] L.F. Richardson, Weather Prediction by Numerical Process (Cambridge: Cambridge University Press, 1922). Reprinted with a new introduction by Sydney Chapman (New York: Dover Publications, 1965).

Shed Season

At the time I made the Ruleset Paintings, I was working for the Montana Department of Natural Resources and local government and maintained an art practice in a shed in the backyard of my home. Spring in Bozeman was a period of time I affectionarely termed 'shed season' as our landlord had removed the ad-hoc barrel stove that heated the structure after my first winter (he feared my heavy use would burn the structure to the ground). Without heat, March was usually too cold to work outside, but come April, things were back in play. The air was sweet and temperatures were warm enough that, with a few warm layers, one could paint for a full day.

The shed itself was more put together inside than its sagged and peeling facade would give away. Bare wood walls framed a floor of plywood. Shottily wired electrical outlets ran throughout the space, also threatening to burn the shed down, but allowed for enough lights and tools. Negotiating space with the others in the house, I built a tall white wall on wheels so that I could cart it to around the room. This white wall offered a surface for my projections.

To the extent possible, I would arrange my work schedule to give myself more daylight hours to paint and make in this studio. During shed season, I would cart my virtual wall-world to the edge of its open doors and set up in the sunlit yard-side corner. From this position I would work and watch the weather as it rolled in and out of town.

I have tried to describe the significance of this space and routine to those who did not know my habits during those years. I understand that what I describe is some sort of pastoral ideal of a studio art practice, and while this is not untrue (it was lovely), it is also beside the point. What I want to think through is not the shed as an ideal to be replicated but as a particular configuration of space, constraint, and attention that made a certain quality of experience available to me. The power of this space at that moment was its position between things:

model and ground, interior and exterior, home and world, my time and theirs. There is a certain tuning that was available to me at its threshold.

What makes it unique was the particular sensitivity to weather and time that it enabled. From its position, there was a directness to how the world entered into the studio. In its ambience and its rhythm my own models of the world change and become situated in atmosphere, time, and place.

At the time I made the Ruleset Paintings, I was working for several environmental groups on geospatial projects — modeling forest characteristics for wildfire risk, soil types for rangeland restoration, water quality indices for riparian interventions. This work coincided with explorations in cellular automata and a growing interest in computation, modeling, and simulation, including a class at the School for Poetic Computation, a decentralized alternative school that aims to empower people to take control of their software and hardware and to see the poetic potential in these tools. Through my art practice I had an interest in feeling the relationships between weather and ground, abstraction, and the geospatial model acting on the world.

The studio practice itself was less about resolving that relationship than inhabiting it. It was my time. And it was, I think now, a different way of knowing the same landscape I was modeling for others; structured around what the model necessarily excluded: a certain amount of unknowability in its thickness and tangles.

Neimanis and Walker's concept of weathering offers a way of naming this. Writing about climate change and bodily experience, they describe what they call thick time, a temporality that is layered, slow, and inhabited. To weather something is not to predict it or manage it but to be changed by it, gradually and without full awareness. This is perhaps shed season's affect. The paintings that came out of that spring were not about the weather as subject necessarilly, but were made inside it, in its rhythm, in the particular quality of light and temperature that a Bozeman April produces. These paintings were weathered by routine, and the comings and goings of place. [3]

The shed studio was an instance of this time, space, and mildful state that I think produced a certain kind of work. It was also a place where the weather still arrived on its own terms, and where that arrival still had somewhere to go.

Top: Figure 2. Image of the shed studio interior. June 2023.

Middle: Figure 3 Ruleset Painting 3 in progress

Bottom: Figure 4 The shed's exterior in Bozeman Montana.

Artistic Research

Kathrin Busch in her writing on artistic research and the poetics of knowledge, describes the epistemic position of an art practice in relation to the sciences, that art constitutes a distinct form of knowledge because it can refer to what scientific knowledge necessarily excludes. The various orders of knowledge produce their knowable worlds by foreclosing others. In my instance, the geo-spatial model renders the landscape legible by stripping it of the many qualities that make it a place. What art can do, in Busch's reading of Foucault, is make visible what hegemonic models cannot hold. Not as a competing claim to truth, but as a different relation to the world altogether. [4]

This distinction matters for how we understand artistic practice in relation to the proliferation of epistemic apparatuses and the monopoly of knowledge production by devices such as the weather forecast described in this essay and broader curatorial project. The forecast attempts to operationalize uncertainy as probability, producing a world that has already been decided in its possibilities. Artistic research can operate at poorly-delineated boundaries, between disciplines, where knowledge has not yet been reduced to concepts. At this threshold certain forms of worlding and forecasting are possible.

Footnotes

Giorgio Agamben, "What Is an Apparatus?" in What Is an Apparatus? and Other Essays, trans. David Kishik and Stefan Pedatella (Stanford: Stanford University Press, 2009).

L.F. Richardson, Weather Prediction by Numerical Process (Cambridge: Cambridge University Press, 1922).

Neimanis, Astrida, and Rachel Loewen Walker. "Weathering: Climate Change and the 'Thick Time' of Transcorporeality." Hypatia, vol. 29, no. 3, 2014, pp. 558–575.

Busch, Kathrin. "Artistic Research and the Poetics of Knowledge." Art & Research: A Journal of Ideas, Contexts and Methods, vol. 2, no. 2, Spring 2009.

Part 4

With Uncertainty

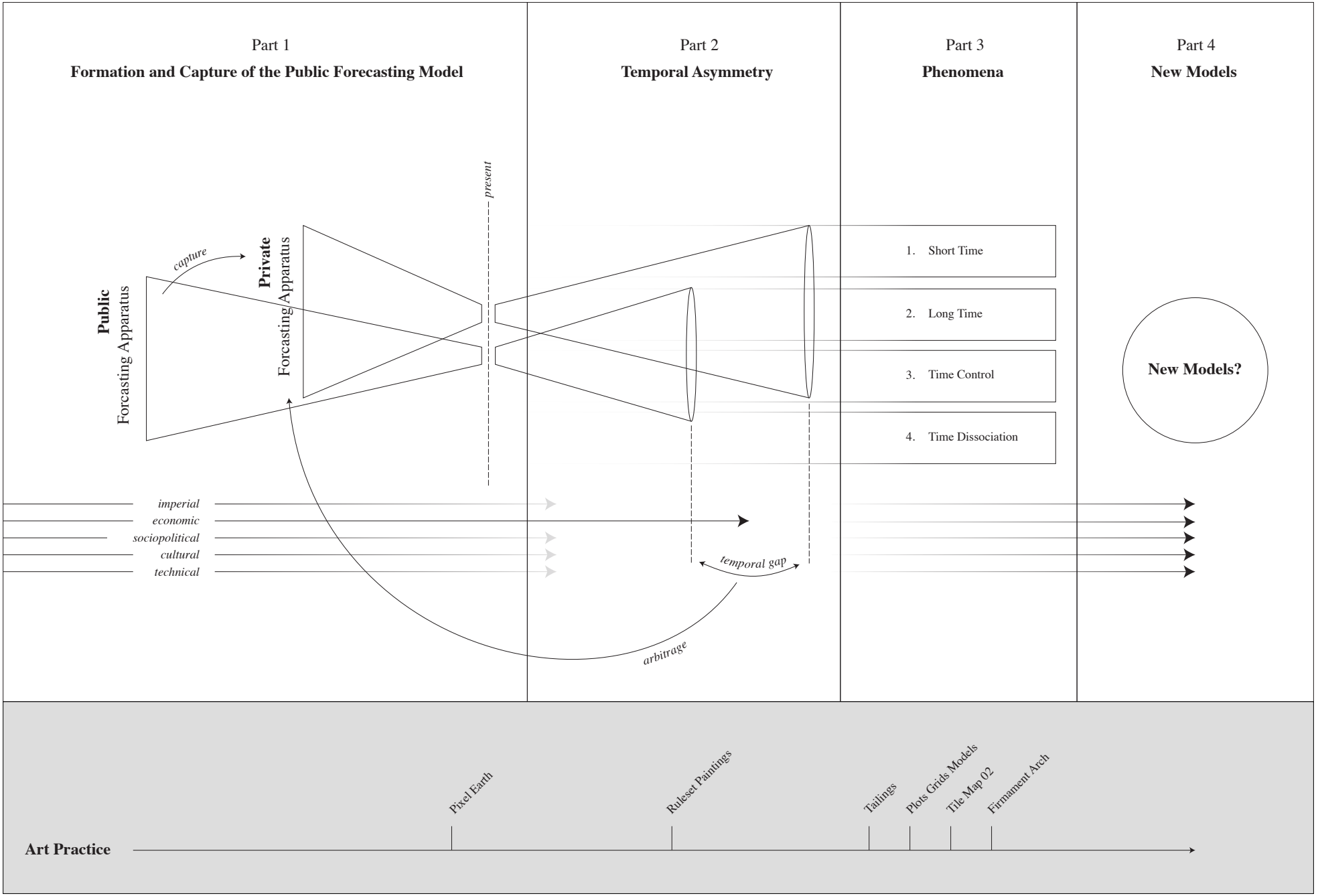
Conclusion

The privatization of weather and climate forecasting has produced a device of temporal control registering across four categories of temporal phenomena.

First across short timescales, proprietary forecasts enable financial actors to extract temporal arbitrage through weather exposed derivatives and other assets in a form of high-frequency trading and model accelerationism. Second, at longer scales, proprietary climate risk models enable the silent evacuation of capital from vulnerable geographies before public awareness, producing forms of climate redlining and reshaping entire landscapes through insurance withdrawal and real estate repricing. Third, these forecasts extend into atmospheric intervention itself—geoengineering, cloud seeding, large-scale infrastructure projects—wherein the forecast logic becomes a mandate to manage uncertainty and control planetary systems rather than live within atmospheric contingency. Fourth, at the level of subjective experience, the forecast severs us from embodied, immediate relations to atmosphere and weather, replacing direct atmospheric knowledge with mediated consumption of institutional predictions and its downstream effects.

Across all registers, the forecast presents itself as a view from nowhere, a planetary perspective that claims objectivity and universality while actually encoding the interests of financial capital or state control. This totalizing vision, obscures the situated, partial nature of all knowledge.

The forecast's apparent totality hides the precarity built in its image: evident in the global polycrisis we now face and continue to image with increasing resolution. But alternatives already exist, embedded in a breadth of practices, historical precedent, and relational logics that refuse the extractive and totalizing frame the forecast imposes.


Part 1
Formation and Capture of the Public Forecasting Model
Part 2
Temporal Asymmetry
Part 3
Phenomena
Part 4
New Models
present
capture
Public
Forcasting Apparatus
Private
Forcasting Apparatus
1. Short Time
2. Long Time
3. Time Control
4. Time Dissociation
New Models?
imperial
economic
sociopolitical
cultural
technical
temporal gap
arbitrage
Art Practice
Pixel Earth
Ruleset Paintings
Tailings
Plots Grids Models
Tile Map 02
Firmament Arch

The Almanac and Situated Forecast

Before, and alongside, the planetary forecast there are many conceptions of weather and world. Versions of tradition ecological knowledge, the almanac, and other vernacular ways of knowing weather tended to situate weather as embedded in time, place, and community purpose. Crucially, these forms of forecasting largely did not seek to eliminate risk and uncertainty; but to build more resilient practices around them, accepting contingency as a fundamental feature of living in an atmosphere.

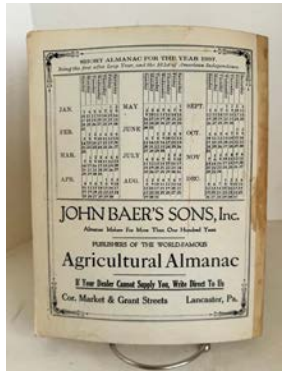
The almanac was less precise in its predictive resolution but often far richer in its relational ecology. Almanacs were produced for agriculture, or navigation, or a specific region and season. Almanacs also included perspectives perepheral to the domain it was forecasting for, such as local politics, culture, and tools. These devices resulted in more resilient networks of dependence: farmer networks, maritime communities, regional knowledge systems, and each were connected by the uncertainties they navigated.

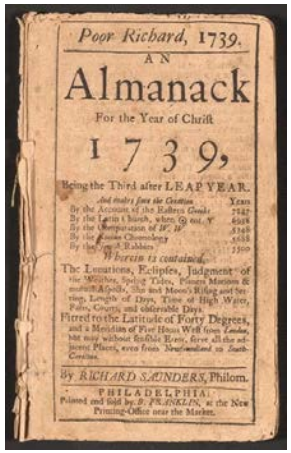
This is not a call to return to pre-modern forecasting. Rather, it is to recognize that different logics of prediction produce different institutions, networks, and material arrangements. The planetary forecast, now financialized into an instrument of capital accumulation, treats uncertainty as a problem to be managed, hedged, and exploited. The almanac, by contrast, treated uncertainty as something to be lived with, understood locally, and incorporated into collective practice. I believe that accuracy only matters in that it produces more just and livable futures, and it is clear to me that from the various registers of the privatized planetary forecast, we could do better.

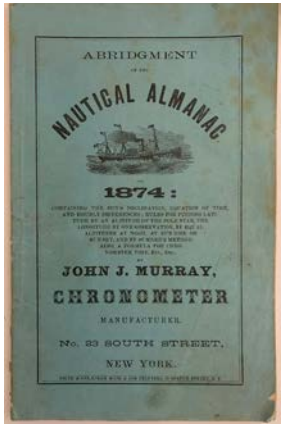
Artistic Practice and Others

Woven throughout this essay are a collection of artistic projects that attempt to reveal peripheral conditions of the modern forecasting apparatus. These projects exist to put forth a practice as evidence of one's subjective experience and way of relating to a world, of which there are obviously many. I have included a breadth of projects as a way of evidencing my practice, rather than presenting them as terminal products. In the spirit of uncertainty and weathering, both these works and this essay remain open and incomplete.

Running through the body of work I have included is an interest in the copro-







duction of models, landscape, and culture.

Together the essay serves to frame the the work's preoccupation with the model and its world-making potential. Embedded in this coproduction of the model and the ground, is a kind of agency that is asscribed to one's attention and organizational cuts, to our collective attention and collective organizational cuts. Just as the Black-Scholes algorithmic trading scheme reorganized markets in its image, we might find that art and other softer forms of modeling have the same potential. If this essay has a clear proposal it is that we need a plurality of ways to know and relate to future uncertainty, and that the way we build our models are coproductive with the world.

New Models

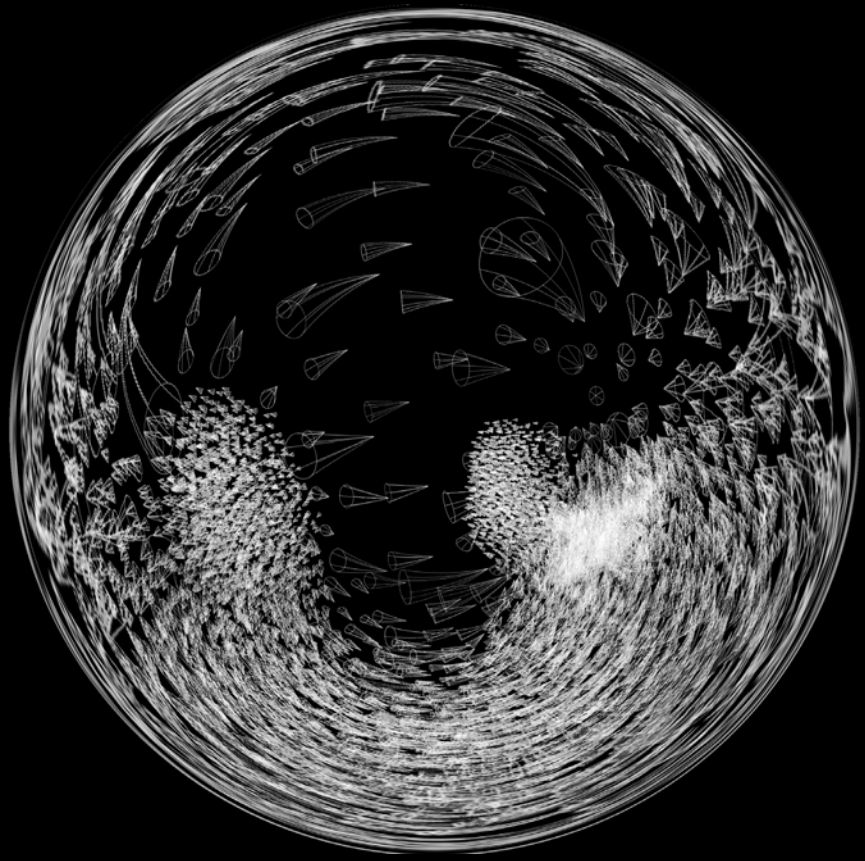
The structures of financial capitalism give shape to something true about our collective condition: that we are indeed entangled and that the nature of our world is one of positions on positions on positions. This interdependence of variables: what our peers do, how the atmosphere moves, what our internal preferences might be in the future, all carry risk defined by the fundemental truth that the future is unknowable.

In financial markets surrounding the forecast, every agent looks at every other agent's projections, and their projections of another's projections. What results is a network of relations that forms a malleable shape that spirals up or down, but always reforms with more complexity. The ordering logic of these agents are to make one's own future more certain by either 1) diversifying and hedging risk across a range of abstract financial products, or 2) by preempting the movements of others through assymetric information about the world, or the movements of the system itself.

Unfortunately, all of these agents seem to share a relatively homogenous model of financialized time, possible worlds, and the ordering logic that forms their relationship with uncertainty. So close! What perpetually evades critiques of capitalism is predictions of its collapse. In crisis after crisis these markets reorder, or markets respond to ground in ways that don't map to how prices might logically be. There is a certain dampening to ground conditions that the shape of finance has discovered.

Is it possible to reorder the logic driving these agents so that we might preserve some architecture of its relations, but correct for the stability of the system as a network? How do we preserve this resilience while also accounting for conditions on the ground? If each agent using the private forecasting model is oriented by capital accumulation as a means of protecting against the future, what orienting rules could there otherwise be?

These questions are not new, and many others have written about the possiblities. What I hope to add to the conversation is to orient these perspectives of worldmaking at the weather forecast as a device of significant consequence and to reopen its technical instraments, institutions, and models for consideration based on the phenomena they, and the world intra-act.



Model 17 (Almanac - July)
watercolor, gouache, and ink, on paper
40x30 inches
2026

Model 17 (Almanac - July)
watercolor, gouache, and ink, on paper
40x30 inches
2026

MDes Open Project: Energy Dreams

The planetary crisis is inseparable from extractive geographies that render land, labor, and atmosphere as resources accelerating further climate breakdown and deepening social inequity through the feverish rush for energy transition minerals. These resource logics transform expansive territories into sites of extractive processes, embedded inhistorical patterns of accumulation that persist over time. Such systems cause differentiated harm and maintain power asymmetries across environmental, social, and political domains.

In 1876, Philadelphia's Centennial Exhibition, the 'International Exhibition of Arts, Manufactures, and Products of the Soil and Mine', rendered territories as specimens, extraction as capital, and dispossession asan acceptable byproduct of these acts of classification. The exhibition staged the American landscape as an inexhaustible resource, showcasing the Appalachian coalfields, the Great Plains grain, and Southern cotton as material evidence of Manifest Destiny.

This open project aims to revisit that exhibition to trace the extractive geographiesit celebrated to their present conditions of depletion and toxicity and to the planetary crisis. The landscapes displayed as national wealth in 1876 now constitute the infrastructural and atmospheric conditions of theplanetary crisis. From Pennsylvania's coal seams to the petrochemical corridors of the Gulf Coast and from Midwestern aquifer depletion to mountaintop removal in West Virginia, these landscapes that were once celebrated remain active sites of extraction, toxicity, and contestation.

The open project considers ecology as entanglement, drawing on the works of Barad, Haraway, Stengers, Yusoff, and Liboiron. We define these extractive geographies as sites of deep accumulations of geological, colonial, and labor histories entangled across space and time.

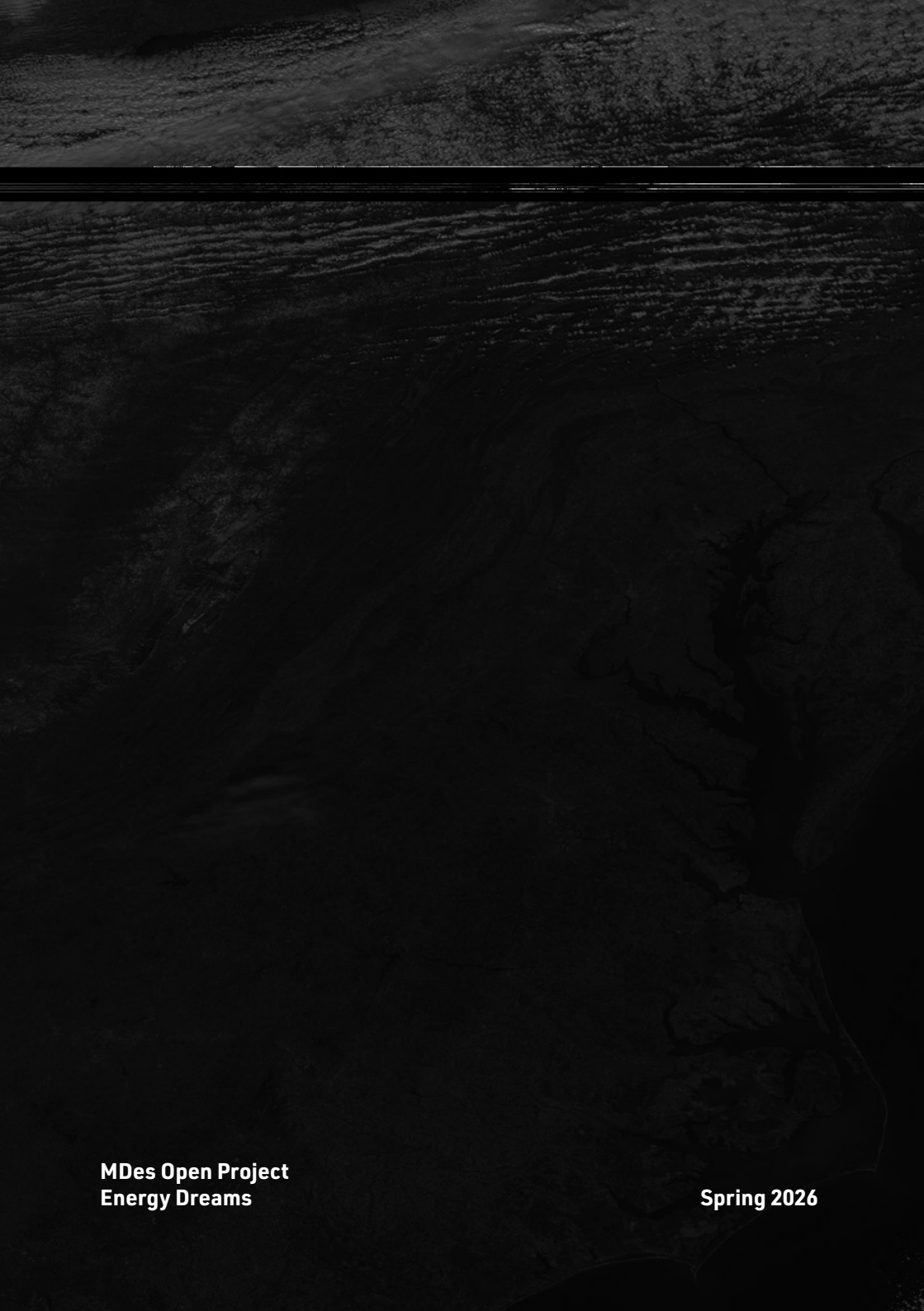
Each student will engage with a distinct extractive geography through archival research and the creation of situated counter-narratives. These records will then be reassembled at a fictional Fairmount Park for the Counter-Centennial Exhibition. This will not be a display of territories but a forum constituted by them, where the extractive zones can speak back and propose reparative design actions that contribute to the exhibition's legacy project.

About

Eric Rannestad (b. 1996 - Chester, Connecticut) is a Montana-based artist making work about the systems and technology that humans use to compartmentalize, measure, and model the world. The current work speculates on the infrastructure of the built environment through sculpture, painting, and digital media.

Informed by the economic, natural resource, and architectural models shaping our built environment, these projects contemplate the 'model' as an attempt to control the compounding crises of our present moment, and as an act of imagination. Pre-scientific cosmologies, market frameworks, and mapping technology inform the work's medium, imagery, and form.

Eric received a BA in Studio Art and a BA in Environmental Economics from Whitman College and is a Master of Design Studies (MDes) candidate at the Harvard Graduate School of Design. He has attended fellowships at the Vermont Studio Center and I-Park Foundation and attended residencies at the Wassaic Project, Sitka Center for Art and Ecology, and more. Eric also completed a certificate in GIS + Design from Pratt Institute and was a participant in the 2018 New York Arts Practicum. His commercial projects in cartography and work experience in environmental conservation across the American West are a significant influence in his art practice.



MDes Open Project
Energy Dreams

Spring 2026