Weather as Medium

Toward a Meteorological Art

JANINE RANDERSON

3 Weather Envisioning: Visualization and Mapping

Digital culture opens out to the weather, forging new alliances among art, science, social life, and the physical world to predict the weather to come and to model change over time. Our desire for an instant daily weather report calls for new imaging processes, and techniques of disseminating information. With new media art, the difference between creative and scientific means of meteorological representation has diminished; artists use the same tools and meteorological data streams as scientists to gather digital weather media for their practice. In the age of big data, dense tracts of information from remote-sensing satellites is plumbed by supercomputers and classified weather knowledge is held in powerful international conglomerates to be bought and sold. Under these conditions, artists' resourcefulness in accessing weather media becomes critical. Artists conjure representations of weather from contingent, confounding, and often difficult to access data sets to sensory and political effect.

Meteorological scientists and visualization experts turn the numerical data from instruments into recognizable visual schemas, whereas artists look for gaps in these maps. I begin by charting some conventions of meteorological data visualization, from hand-drawn notations to satellite meteorology, before turning to artists' aberrant mappings. The repurposing of digitized weather for art is described here as *data hitchhiking* to draw out the complex relations between artists and scientific information. In *Most Blue Skies* (2006–2009), British artists Lise Autogena and Josh Portway hitchhike on existing data streams controlled by a network of governmental meteorological agencies to speculate on how we perceive. Entirely new weather schemas emerge in installations by Thorbjørn Lausten (Denmark) and Billy Apple (Aotearoa New Zealand). Korean artist Zune Lee's game *Weather Pong* (2011), a variation on the classic Atari arcade game *Pong* (1972), politicizes social activity by combining weather-mood correlations on Twitter and atmospheric data streams. *O-Tū-Kapua: My Personal Cloud* (2016–2017), by the art collective F4 (Aotearoa New Zealand) and Aotearoa New Zealand's National Institute of Water and Atmospheric Research (NIWA), binds climate science and Māori customary knowledge of weather. Such meteorological artworks act as unruly mediators for humans and our technical instruments with the physical and spiritual worlds.

When Hannah Arendt reflected on space technologies in the 1960s, she found that modern science has shown us vast gaps in our knowledge of nature that escape not only the "coarseness of human sense perception but even the enormously ingenious instruments that have been built for its refinement" (2006, 261). Arendt evokes Max Planck's observation that data sets, for physics researchers, are like "mysterious messengers" from the real world. In weather-forecasting, we only know about future weathers when shifts in light and heat affect our measuring instruments on distant satellites. Transmutations take place between the numerical language of measuring instruments, the swarms of data they generate, and their final translation into pictures by visualization professionals. Perhaps because of the gaps in our knowledge, a tacit acceptance of scientific knowledge and computational mechanisms has emerged, as Vilém Flusser ([1985] 2011) has argued. Yet for Flusser, those who visualize information are not merely working in service of science and industry; they are "envisioners" of our social world who draw out the visual patterns that impact our lives. An artist teases apart accepted data routes and normative software interfaces to diversify the number of stakeholders who envision the atmosphere.

Digital anemometers, barometers, and satellites are essential to scientists as sources of data for computer-based visualizations and climate projections to represent the atmosphere—only to become invisible once maps have been made to communicate the weather. The maps themselves are eventually discarded as yesterday's news. I was given thousands of black-and-white printed photographs of satellite clouds that had once been used by the Bureau of Meteorology (BoM) in Melbourne to make analogue animations for televised weather forecasts—now useless objects to meteorological forecasting, but still captivating documents to me. The humanities have historically "banished" technological and informational objects from the "world of meanings"; as Simondon (1958) argued, they are considered neither human nor natural. On the other hand, aesthetic art objects, such as Turner's *Clouds*, have been given special attention in cultural discourse, as indeed they have in this book. Yet, like many artists, I am intrigued by weather instrumentation, meteorological maps, and satellite images as compelling entities in themselves.

Meteorological Visualization and Mapping

Scientists and visualization experts translate weather phenomena into maps and diagrams using codified color schemas and regulated instruments and software. By employing a homogenous language (longitude and latitude, geometry, time-space axes) the weather map defines the way we understand borders, much as we understand the geographical markers dividing sovereign territories. Such geopolitical borders are clearly imposed despite the lived reality of cultural-linguistic regions, and they are subject to historical movement. Much the same can be said of boundaries constructed in meteorological maps. Latour (1986) coined the term *immutable mobile* to describe how scientific visualizations have the property of mobility to convince dissenters or raise financial resources. Yet they are immutable as they are encoded with particular formal features. A weather map organizes our pursuit of agriculture, leisure events, and travel, so it needs consistency. Repetitive processes keep particular paradigms stable, and, as such, meteorological visualizations are repeatable "gestalts" that we all recognize (Ihde 1998). For general acceptance of a form to take hold, Nigel Thrift argues, their forms must be "reliably repetitive" and "consistently consistent" to be understood and to compel (2004, 177). Artists, on the other hand, will often seek formal deviances, rather than the restrictions of repeatability, or they will invent their own schemas.

In the era of expanding empires, maps of prevailing winds oriented ships along sailing routes. An elite number of citizens could imagine that they "gathered up the world" using visualization of the winds to speed their passage to remote lands. Early maps of the trade winds, for instance, were used to advantage ships in their journeys between Europe and the Americas. According to Latour, visualization is about persuasion. He characterizes the role of a map as follows: "You doubt what I say? I'll show you. And, without moving more than a few inches I unfold in front of your eyes figures, diagrams, plates, texts, silhouettes, and then and there present things that are far away and with which some kind of two way connection has now been established" (Latour 1986, 13). Visualization remains one of the most powerful explanations to muster allies to a cause. Through the opening of visualization processes to a non-scientific audience, artists create new ways to envision, revisit, or resist the power relations of meteorological mapping.

During the Enlightenment, objective reality began to be divided into quantifiable units—from dots and dashes to indicate wind direction to fractions and decimals in mathematical notation to bars and measures in musical notation to perspective in painting, drawing, and cartography. At the same time, graphic marks of weather began to be layered over the contours of the land masses; both cartographic and statistical systems of representation converged on one map. Edmund Halley's early meteorological map of tropical airflow (1686), for instance, layered data about prevailing winds, magnetic variations, and tides from ship's logs to construct a map of tropical surface winds. Halley annotated his isometric projection map with short, swirling dashes to indicate wind direction (Tufte 2001, 20). This process of abstracting nature, Mathew Fuller observes, turns “a live thing, a dynamic, or an object into something that exists as a numerical representation of its properties, or that has such an abstraction of itself embedded within it” (Fuller 2005, 165). The oscillating dynamic between real and abstract systems of phenomena is a lure for many artists.

Ever since Galileo pictured us wandering in a “dark labyrinth” without God’s geometrical figures as a guide, measurement has been synonymous with positivist science. Yet painting and architecture have historically played a part in the development of mathematical perspective in maps of the globe. Northern Renaissance painter and printmaker Albrecht Dürer’s book on the perspective of the human body, *De Varietate Figurarum* (1537), was circulated widely among cartographers and probably reached Gerhardus Mercator, the Flemish cartographer par excellence. Renaissance perspective in painting gave cartographers the means to reproduce material reality on flat surfaces by using foreshortening, pulling, and stretching to create spatial distortions. The Enlightenment’s cartographic accomplishment of a standardized perspectival earth is only one vision of our world, however. To accept this measured, mathematical version of reality was in fact, as Alfred Crosby (1997) has argued, a blind leap of faith into a particular Eurocentric framework.

For Arendt, the problem with mathematical operations that reduce “sensually given data” to “numerical truths” is the removal of the “eyes of the mind, no less than the eyes of the body, from phenomena” through the force of distance. She writes, “Under this new condition of remoteness, every assemblage of things is transformed into mere multitude, and every multitude, no matter how disordered, incoherent, and confused, will fall into certain patterns and configurations possessing the same validity and no more significance than the mathematical curve” (Arendt 1958, 267). Science and mathematics have come to overrule “the testimony of nature as witnessed at close range by the human senses” and reduce it to the uniformities of geometry (ibid.). Artists instead bring the body and social exchange back into mapping processes.

The empirical weather maps of Indigenous navigators persisted successfully as alternative spatial models, without the mathematics of European maps. Take the Marshall Islands’ cowrie shell, coconut fiber, and stick maps, for instance, that convey complex information such as ocean swell to guide seafarers around Micronesia. In Australia, stringybark paintings functioned in ceremonies to pay homage to local weathers and plant and animal life. In the bark paintings from Arnhem Land in the Museum of Contemporary Art (Sydney) collection, such as Djimbarrdjimbarrwuy’s *Totem Cloud Pattern* (ca. 1970), the graphic marks of wind direction can communicate and without recourse to a numerical system. Spirits lie within these maps that communicate spatiotemporal, social, and atmospheric systems simultaneously (Mundine 2008, 84). Measurement has never been essential to weather mapping; geometry is a culturally inscribed form of representation.

By the turn of the twentieth century, technologies such as radio and the telegraph were used to communicate weather forecasts, largely by observing how fronts traveled from place to place. Ground-based observations in Australia were delivered by telegraph infrastructure to forecast weather between states. If Melbourne experienced rain and a southerly wind, for instance, the same conditions would soon come to Tasmania. The telegraph networks were extended to deliver warnings about the coming weather fronts that drifted across the Tasman Sea to Aotearoa New Zealand. A crucial point in the predictive numericalization of meteorology came in 1904, when Norwegian meteorologist Vilhem Bjerknes claimed weather forecasting to be a problem of physics (Friedman 1989). Ruling equations could be predicted based on recent observations of an initial state of atmosphere. By 1950, early computers enabled the numerical prediction of weather that Bjerknes anticipated: programs could plot weather from one point to another to convey future weathers.

From the first kites equipped with meteorographs in the late 1890s to the panoramic sweep of the weather satellite image, meteorology from above changed forecasting forever. A transfixed television audience viewed large-scale cloud formations from space for the first time via the Television Infrared Observational Satellite (Tiros I) in 1960, at the beginnings of remote meteorology. The cloud patterns were interpreted as "signatures" of the weather systems that would impact the earth far below. Morris Tepper, deputy director of the Space Applications Program at the National Aeronautics and Space Administration (NASA), stated in 1960 that "pictures taken by the Tiros satellites showed that the Earth's cloud cover was highly organized on a global scale. … The cloud structure as seen by Tiros has been superimposed on the weather map. It is remarkable how closely the cloud systems delineate the weather systems. It is as if Nature were actually drawing her own weather map directly onto the Earth" (NASA 2012). Tepper's enthusiasm for the inscription of nature via technology echoes Henry Fox Talbot's mid-nineteenth-century understanding of solar photography in his book *The Pencil of Nature* as both a natural and a cultural phenomena (Batchen 2002, 10). Both suppress the complex technical operations involved in making images to naturalize an emergent technology. A television "weather lady" would further feminize this technological assemblage as a form of infotainment.

Satellite imaging plays a crucial part in contemporary accounts of the weather system as global and interconnected. After the first Apollo mission, camera-based photographs were no longer taken from space; instead, binary codes were computed from a flow of numerical data to create images. Virilio (1994) describes satellite perception as "sightless"; numbers stand in for physical phenomena that humans must visualize. The vast improvement in the accuracy of mid- and long-range weather forecasts justified the enormous financial and computational power needed for the maintenance of satellites. Transgovernmental meteorological institutions released a limited amount of declassified weather satellite data to the public through popular television or radio and later as continuous real-time uplinks to satellites. However, most weather data is still withheld for scientific, military, or commercial applications. For Foucault, the satellite is a "disciplinary apparatus" from space, a "mechanism that coerces by means of observation" (Foucault 1979, 170). The overlaying of lines demarcating territorial boundaries between regions or countries is a convention of satellite weather imaging derived from military operations to render them readable.

When weather is represented from numerical data and false-colored by a visualization expert, science's hermeneutic practices become opaque. The outline of the isobars become the traced "figure" against the "ground" of a territorial map. By the 1980s, Flusser proposes, the "technical image" had fundamentally transformed our modes of cognition. We moved from an alphanumeric process, in which pictograms were lined up to tell a narrative, to the current chaotic "swarm of particles" and "fields of possibilities" of digital code (2007, 19–21). The new role of the visualization expert, or Flusser's "envisioner," is to "press buttons to coax improbable things from the whirring particle universe that the apparatus is calculating" ([1985] 2011, 37). For Flusser, the automatic dissemination of calculated numbers by computer deposes linearity and challenges the human imaginary to new modes of thought.

There are constraints nevertheless on contemporary visualization processes; weather maps are unable to include all phenomena in their sample size, so they reduce information to the measurable. In weather measurements, phenomena are split into unit variables like temperature, pressure, wind speed, and direction and reassembled by apparatus and maps. The sample size is limited by the fact that we only receive data in zeros and ones, leaving no room for the infinitesimal measurements of our phenomenological reality. In a presentation at the *Data Landscapes Symposium* hosted by the Arts Catalyst in London, scientist David Walton stresses that nothing is certain in measurement: "Data models are based on very large grids with a lot of information missed in-between" (Walton 2011). Each margin of error has potential to accumulate. In addition, supercomputers deal in scales of data processing that are too large for human comprehension; working in patterns simplifies data sets to make them readable again. Not only is information missing, but the original data sources become all but invisible; we know little about the instruments that capture phenomena or the algorithms that underpin the software we rely on. Our own physical actions are quietly tracked by software, and in biophysical terms, we are playing a role in the feedback loop with the sensitive atmospheric system. Artworks render visible such patterns of activity with the physical atmosphere, and set these in relation to instruments of weather monitoring and visualizations of weather.

Artists and Satellite Weathers

Artists, unlike scientists, have traditionally operated in the realm of the unmeasurable; sensations are created perceptually that cannot be described mathematically—for example, qualities of shape such as roundness, smoothness, or the subjective operations of color. In science, atoms, particles, photons, or genes are designations of primary qualities of things, and qualities such as colors, odors, or lights are secondary. While the primary qualities of things suggest universality, the secondary qualities have traditionally divided us according to the specifics of our geography, our languages, our cultures, our cosmologies. Artists often draw together so-called primary scientific systems of measurement and secondary sensory qualities. The tradition of scientific empiricism needs to understand phenomena through standardized routines of demonstration, but artists are concerned with variation. Scientific visualizations strive to communicate clearly, yet many artists eschew an informational function entirely. The communication of useful facts is only one conceivable result of measuring and visualizing the weather.

For much of the twentieth century, restricted access to computerized weather data meant that satellite weather media was out-of-bounds for artists. Yet artists still subverted the political potency of the cartographic map, such as in the Uruguayan modernist Joaquín Torres-García's *América Invertida* (1943), used politically to draw attention to South America's marginalized global position. In Torres-García's map, the sun shines brightly over an upside-down South America; weather is used symbolically to represent the hope of a political revolution. The psycho-geographic maps of the situationists and the nonlinear device of the *dérive* anticipate the meandering flows of information that are a feature of contemporary culture and art. By the closing years of the twentieth century, both scientists and artists could access weather data in digital forms online, albeit with unequal access to classified data.

Although the blind vision of satellites compresses weather phenomena into digits, they offer a mobile vista that supplants anything we ourselves can reach unaided, as Lisa Parks (2007) has argued. Parks describes artists who engage with satellite materials as "satellite translators" who unbind satellites from predetermined military and industrial uses in favor of aesthetic-phenomenological explorations. Rather than positioning satellite weathers solely as a hegemonic form of data production, artists approach satellite visualization as an affective arena that far supersedes their surveilling function. Satellite imaging appeals to artists and scientists alike by opening human perception to scales we cannot sense. We find a scopic pleasure in "seeing the whole," as philosopher Michel De Certeau writes (1984, 92), an aerial lift into voyeurism, now widely available via the Internet weathers sourced from remote satellite. The chief threat of this panoramic perspective is the one-sidedness of the gaze, where the detail disappears into the context, in the "vertigo of distance." Yet the ideological values and dangers of *un regard surplombant* (a look from above) that De Certeau questions, when encountered in art, do not necessarily suppress local and experiential knowledge.

Recent art installations by Billy Apple, Thorbjørn Lausten, and Lise Autogena and Josh Portway perturb the binary distinction between distant meteorological satellites and earthly weathers. Apple's *Severe Tropical Storm 9301 Irma* fuses the satellite view of storm Irma from above and his encounter with the same storm at sea, whereas Lausten's video installation *Magnet* (2008; figure 3.1) elicits a sensory-perceptual, embodied response to color fields produced by live satellite meteorological data. In Autogena and Portway's *Most Blue Skies* (2006–2009), the same data used by scientists for measurement has a qualitatively different purpose: to assess "blueness." These artworks hitchhike on existing meteorological data streams to immerse us in the transient effects of weather. Satellites are perceptual devices that operate with senses (or sensors) that are designed by humans, yet we can still be surprised by the sensory experiences they produce. Although the weathers detected by satellites imitate our own intellectual efforts of perception and memory, they are not bound to the physiology of a human body. Artists bring the body back into account.

Thorbjørn Lausten: Perceptual Maps

The installation *Magnet* (2008) hitches onto live geomagnetic and meteorological data from Scandinavian science institutions. The artwork is an abstract grid of pulsating colored shapes based on the live feeds of physical phenomena. Lausten's visualization was projected in an exhibition space at ZKM Center for Art and Media in Karlsruhe, at the same time as it appeared on a public web page on the Internet, engaging both an online and an onsite audience for the work. In the gallery, each projection divides into four weather zones, with a series of potential color responses to a flux of weather and geomagnetic measurements. The numbers are converted into 256 color values that flicker and change along with the weather, leaving powerful afterimages. Geomagnetic

Figure 3.1
Thorbjørn Lausten. Magnet. 2008. Installation view at ZKM Center for Art and Media, Germany. Software and four video projections. Photograph: ONUK (ZKM Center for Art and Media, Karlsruhe). [See color plate 4]

data was continuously supplied from four measuring stations in northern Norway and processed by the University of Tromsö, Norway. The geostationary satellite Meteosat, positioned above the equator, transmitted infrared weather data visualized as shifting color fields every fifteen minutes. Four areas of meteorological and geomagnetic information from Aalborg, Guldborg, Roskilde, and Karlsruhe were selected by software written specifically for the project. These fifty-kilometer by fifty-kilometer physical zones correspond to the four color zones of the installation, although the shapes produced are abstract, without recognizable local features.

Like Hans Haacke, Lausten describes his artworks as systems, but in this case as visual systems. Lausten told me that he sees the field of data visualization as entirely open because neither artistic nor scientific expertise has clearly defined or claimed this area. The ever-changing meteorological data itself also provides an open field of possibilities. Familiar hexagonal, circular, or rectangular shapes create perceptual gestalts in which weather variables become optical sensations that have no immediate reference to a conventional weather map. As we have seen, scientists use color and figure/ground relations in visualizations hierarchically to draw attention to specific information. Instead, Lausten uses color to create a moving abstraction of an existing data stream. These abstract color-fields make us aware that data is recomposing our senses, as opposed to a scientific visualization that directs vision along culturally learned lines. Color can only be understood through vision, so Lausten harnesses a unique aspect of human sense and ties it to nonvisual scientific data. Although the mathematical (one-to-one) correspondences between color data and weather data may be described as isomorphic or equal, they also share a homologous structural effect, as both color and weather create optical, haptic sensations in the body. Weather shifts and perceptual sensations in the body also share correspondences as they are mutable and temporal.

In scientific visualization, the geometrical orientation of perspectival maps that have been transferred into regimes of colors are the outcomes of the standardized grid of the raster array. The gridded array is also at the core of dominant media forms of spreadsheets, maps, and databases that are the substrata of visualization technologies in social management and science. Yet in the hands of conceptual artists—take Sol LeWitt, for instance—mathematically structured wall drawings undermine the expectations of the regimental function of the grid to defy perceptual logic. LeWitt writes: "Logic may be used to camouflage the real intent of the artist, to lull the viewer into the belief that he understands the work, or to infer a paradoxical situation (such as logic vs. illogic)." (1967, 79). Visualizations working from numerical data can only ever be as open as whole numbers will allow, just as grids cannot take in all the contours of a territory. Lausten works within the confines of gridded data, yet the retinal response to the colors in randomized sequences is generated from unpredictable combinations that emerge from the weather itself. The physical sense of disorientation in the body produced by the afterimage of the geometrical pattern undoes the regimental function of the grid arrangement by confounding logic, in Sol LeWitt's sense.

Instead of occupying a god's-eye view of the weather system from above, Lausten's perceptual schema produces a weather-like bodily experience. *Magnet* activates my senses through the optical play of color afterimages. Retinal effects, such as a red afterimage following a green shape, interferes with the smooth transmission of the weather data in a logical manner. As the afterimage from the video shapes forms, I catch myself in a process of seeing. The perceptual effects forming inside my retina spill into the dynamic space between myself and the data screen and outwards toward the shifting weather. In *Magnet*, a new system of weather visualization emerges, based on pulsation, movement, and temporal responsivity—more closely aligned with winds, clouds, solar winds, and magnetic fields produced by the sun. Conventional whole-earth-mapping

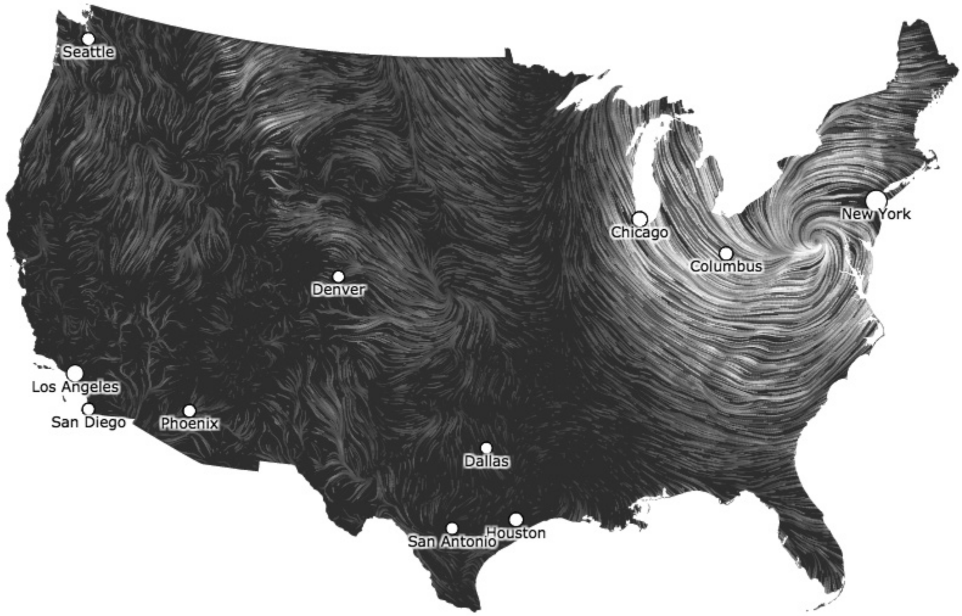

Figure 3.2
Martin Wattenberg and Fernanda Viégas. *Wind Map*. 2012. Screenshot of online artwork. With permission of Martin Wattenberg and Fernanda Viégas.

features such as longitude and latitude, geometry, and time-space axes disappear. The weather map now exists in between the perceiving observer and image. *Magnet* is literally made up of natural phenomena, but the work is not about nature in the Romantic sense. Instead, Lausten (2008) draws our attention to weather as an "inseparable part of our own nature."

In other works, the distinction between an art object and a scientific visualization is much less obvious than in Lausten's bold geometric forms that draw on the legacy of concrete abstraction. Visual communicators Martin Wattenberg and Fernanda Viégas's (United States) project *Wind Map* is an intricate, digital drawing of winds over the United States driven by live data feeds in real time. When the work was first made public online, the creators felt bound to issue the following disclaimer on the same page as the artwork itself: "The wind map is a personal art project, not associated with any company. We've done our best to make this as accurate as possible, but can't make any guarantees about the correctness of the data or our software. Please do not use the map or its data to fly a plane, sail a boat, or fight wildfires" (n.d.). The potential threat of false weather information reaching the public through art projects, and causing alarm with unverified data, is a real concern among scientists. I encountered initial resistance from meteorological scientists to share data with me for the art project *Neighborhood Air* (2013) because they had valid fears about “non-quality-assured” data produced by air quality instruments reaching the public unchecked through the online interface. Machinic irregularities are frequent, and aberrant data in science is cleaned up and eliminated by a human safety check. Artists, on the other hand, will often celebrate the machinic glitch. The responsibility is on us, however, to ensure that an artwork doesn’t cause social harm.

Billy Apple: Recomposing a Storm

Wattenberg and Viégas’s visualization could be mistaken for a scientific map, however Billy Apple’s *Severe Tropical Storm 9301 Irma* (figure 3.3) is formally unlike a conventional weather map, yet retains an internal logic that is consistent with navigational charts. Rather than negotiating with science institutions to harness live data as Lausten does, Apple’s departure point is the chance occurrence of a severe storm while he was a passenger on the refrigerated cargo ship *Chiricana*, a vessel laden with high-quality squash for export en route from Napier in Aotearoa New Zealand to Osaka in Japan. On March 15, 1993, as the ship crossed into the Equatorial zone, Tropical Storm 9301 Irma was brewing. Apple describes how the work began as a daily process of gathering weather material on board the *Chiricana*, including printouts of satellite charts of the approaching storm from the radio operator as they came in on the ship’s bridge. He collated entries from the ship’s log book with assistance of the ship’s navigator. Their position in the Pacific Ocean was charted using the marine Beauford scale, used to codify the chaos of real experience into orderly tables of sea states and wind speeds. Later, Apple retrieved satellite weather forecasting data from the Japan Meteorological Agency to track the remote view of the storm from above. In something of an anticlimax, the storm Irma and the ship *Chiricana*’s paths never crossed at the storm’s height—a catastrophe averted. Still, the remote view and the nautical data fueled Apple’s complex audiovisual and typographical schema in *Severe Tropical Storm 9301 Irma*.

A delight in calculation, measurement, and bureaucratic detail are part of Apple’s art practice, along with his formal attraction to orderly disorder in meteorology and navigation. Scientific practices of measuring and diagramming at sea are the compositional spur for *Severe Tropical Storm 9301 Irma*’s five iterations from 1998 to 2015. The site-specific elements of the artwork consist of three parts: an animated navigation map plotting the twin paths of the ship and the storm; two sets of coded typographic scores or sound charts—with thirteen storm charts for the storm and eight charts for the ship;

Figure 3.3

Billy Apple. *Severe Tropical Storm 9301 Irma* (coded schema representing satellite data details the upgrading of the 1993 Pacific Ocean tropical storm to a severe status). 2015. Image courtesy of the Billy Apple® Archive. [See color plate 5] and a large-scale wall painting in pale blue and shades of black, like a tonal bar graph, to visualize the wind and wave conditions during the storm. At the Window gallery in Auckland in 2005, at midday each day (the same time as log entries were made on the *Chiricana*), a sound composition plays in a duet: one stereo channel indicates the ship's passage and the other the rising storm. Like Lausten's *Magnet*, *Severe Tropical Storm 9301 Irma* establishes a language of transactional exchange between art and computational logic.

In the Window gallery, the *Navigation Chart* animation (2002) is bordered by a panel of red lights on the left and green lights to the right—the nautical symbols for port and starboard. The green and red orienting devices bring to mind Ihde's description of the repeatable perceptual "gestalts" used in mapping. Red and green are also recurring colors in Apple's self-branding language. The colors first emerged in his iconic apple Pop artworks, such as *Apples, 2 for 25¢* (1962–1964), as a mnemonic for his new identity as artist. Art historian Wystan Curnow writes that the "commercial ordinariness" of the *Chiricana*, in the business of commodity trading of squash, is "an Apple kind of ship" (Apple et al. 2015, 2). Apple clears away the mess of human emotions in a storm that would characterize such a subject in Romantic art. Yet the artwork is not completely devoid of expressive elements; there is still a sense of compositional drama as the sound intensifies, as the storm and the ship's paths draw close.

The three-step electronic sound score and programming system of *Severe Tropical Storm 9301 Irma* was devised by Apple with composer Jonathan Besser's assistance. A code was developed in letters and numbers to lend sound to the normally silent cartography of the weather map. This alphabetical, numbering, and musical notation system, entitled *Sound System* (2002), is based on the course of the ship from the log book and the remote satellite information tracing the storm's path. Apple pointed out to me that he used red for the numbers and blue for the notes and corresponding numbers and letters in the sound schema, as a reference to the color of the pencils used in the *Chiricana*'s log. Rather than a mere translation of the movement of weather phenomena into sound, curator Andrew Clifford notes that Apple's approach obfuscates information, as an encryption, rather than a sonification process that would disseminate data in "more tangible, more cognitively ergonomic ways" (Apple et al. 2015, 9–11).

In 2015, Apple published an artist's book to further unfold the typographic correspondences between numbers, letters, and musical notes that the storm Irma had become. The book graphically lays out the alphanumerical schema for the severe storm and the ship's route based on the log entries from March 12 to March 18 and digits from the Beauford scale, each matched with a musical note. At its center, a foldout navigation map, condensed into blocks of blue (waves) and black (wind), with proportions derived from the golden ratio, recalls the wall painting of earlier iterations. Where Lausten starts from scratch for his visual system, Apple recomposes his own experience into an eccentric temporal and spatial weather scheme.

In a similar vein, the numerical automation of the weather system is investigated by British artists Thompson and Craighead. The online work *Weather Gauge* (2005) is a digital record of global weather data from 150 countries, constantly updated in real time. We see masses of names of cities on the globe, quickly replaced by the local time, and then the temperature (in Celsius and Fahrenheit) in rhythmical swaths of digits. Thompson and Craighead foreground the statistical analyses and algorithms that drive current understandings of natural phenomena, in a work that overwhelms with the sheer speed and complexity of numerical computation. The particular event of Irma in Apple's weather schema fixes the weather in time, whereas the weather relentlessly rolls across places and time zones in *Weather Gauge* in a constant process of renewal.

Lise Autogena and Josh Portway: Machinic Blue

The algorithms in Lise Autogena and Josh Portway's *Most Blue Skies* (2006–2009) trawl the skies to determine where in the world at any given time is the "most blue." The artwork, first shown in Kwangju in Korea, takes the form of an installation with a simple blue square projection and a global map illuminated with the location of the "most blue" sky. The deceptively simple question of "Where is most blue in the world?" becomes a complex navigation through scores of remote-sensed meteorological data sets to produce a single location in the world with the bluest sky. The research into both human perception and the science required to answer this question was as intensive as any scientific whole-earth data-gathering project for the artists. Fed by live global atmospheric data, the installation continuously calculates sky colors of millions of places on earth at once. An algorithm compares these calculations so that the software can identify the intensity and location of the "most blue sky" in our world.

The color is calculated by simulating no less than the passage of sunlight through the atmosphere, based on the spectrum of radiation reaching the ground, based on the altitude of the ground, time of day, latitude and longitude, air pressure, aerosol density, and water vapor density, among other parameters. A suite of computers is required to perform this big data operation, which points to the genuine possibility of a numerical calculation to answer a subjective question. The artists describe the realization of *Most Blue Skies* as "grueling" in terms of technology development and cross-institutional negotiation (Autogena and Portway 2011). The labor of programming was undertaken by Portway and Tom Riley, and the atmospheric radiative transfer model was based on an algorithm developed by Chris Gueymard to calculate the "most blue." They obtained atmospheric aerosol data from the MODIS (Moderate Resolution Imaging Spectroradiometer) instruments on NASA's Terra and Aqua research satellites and the cloud and water vapor data from GOES (Geostationary Operational Environmental Satellites) and Meteosat satellites. Institutional partners included the Space and Atmospheric Physics Lab at Imperial College, the UK Meteorological Office, the UCL (University College London) Color and Vision Research Laboratory, NASA, and the Physical National Renewable Energy Laboratory (United States). *Most Blue Skies* was dependent on these high-level scientific institutions to access data streams, implicating the artwork in infrastructures of control.

Environmental sensors and the software algorithms that produce visualizations rely on their energy supply, wireless networks, and the rules and protocols of an ever-increasing number of regulatory interfaces. In the era of the predictive power and behavioral monitoring of large companies like Google, as cultural theorist Scott Lash (2010) points out, nonlinearity and self-generating systems are also mechanisms through which capitalist power moves in contemporary information society. Nonlinear dynamics, in computing in particular, has taken on a different meaning now than in twentieth-century discourse; generative artworks do not automatically have transformative potential over the sameness of the commodity market when they are embedded in multinational conglomerates. The dynamic circulation of the meteorological artwork online is thoroughly supported by the information society as a zone of activity within capitalism's intensive cultural networks. New-media art or "digital" art easily can be recuperated into capitalist technoindustrial formations.

Although *Most Blue Skies* is equivalent in complexity to a scientific visualization and relies on much of the same regulatory infrastructure as science and industry, the artists' question remains socially orientated. Autogena and Portway (2011) suggest that an overwhelming beauty is present in visualization "that is very specific to data," yet a political point also emerges. At the outset, *Most Blue Skies* was not intended as a direct comment on the climate crisis, although the artists later stated: "It addresses our changing relationship to the sky as the subject for scientific and symbolic representation: how the hopeful image of the pure blue sky has become problematized and confused: an imaginary and increasingly vulnerable shelter against the uncertain effects of climate change" (Autogena and Portway 2011). There is pathos in the attempt to seek a meditative experience of color in light of the deep environmental ill health of our age.

Autogena and Portway also are concerned with socializing their data sets in several ways. "The most blue" is a culturally specific identification. They found that scientists, who appeared to know the most about color, could not necessarily help them determine their measurements. Eventually, they selected a human color perception model to try and measure blue as it passes through the atmospheric spectrum to the ground. They would often try to contact someone in the place where the "most blue" had been selected, whether it was in the outback of Australia or the heartland of China, to further qualify or augment the data set with everyday perceptions. The artists once spoke to the owner of Al's Trailer Park in the Australian outback for twenty minutes, by telephone, about the blueness of the skies there that day (Autogena and Portway 2011). One participant in the Data Landscapes Symposium (2011) commented that *Most Blue Skies* generates a democratic "citizen blue," as opposed to the individualism of artist Yves Klein's branding of blue. *Most Blue Skies* surely offers a "machinic blue," produced by a computer algorithm, via which the audience becomes part of a global polity of sky watchers who can compare or contradict the software's decision processes.

Art invites us to think about the origins of the technical image. As visualizations become an increasingly natural part of our environment, we need to attend to their conditions of production. The daily selection of the most blue is an application that in the near future we may happily leave to machines on our behalf, just as choosing favorite clouds is computerized in New Zealander Douglas Bagnall's *Cloud Shape Classifier* artwork (2007; figure 3.4). In this software-based artwork, participants select a series of clouds by pushing one of four buttons on a projected grid connected to a computer. The *Cloud Shape Classifier* eventually will offer a profile of your favorite cloud type depending on your selection from an initially random set of cloud shapes. The endless stream of satellite and other atmospheric data offers only one choice of blue in *Most Blue Skies*, yet it is part of an ever-changing sequence of events. Our choice of cloud, or blueness, allows these machines to learn about human nature.

French-Chinese artist Maurice Benayoun's interactive work *Emotion Winds* (2014) sources "emotional" data from 3,200 cities to form a pattern of the winds laid over a global map. I notice that Aoteaora New Zealand disappears under a swarm of lines representing our heady emotional traffic sourced from online posts. The linear tracks of wind recall Halley's Enlightenment isometric projection map with its rhythm of swirling dashes, and the softer contours of Chinese ink drawings. Visitors can "play the emotion strings like a musical instrument" (Benayoun 2014); the piece also produces the sound of the crowd as we move closer to a particular city. *Most Blue Skies, Emotion Winds*, and *Cloud Shape Classifier* make apparent the ubiquitous presence of calculative processes in daily life online, and the availability of our data to capture and manipulation. Social media platforms such as Tumblr, Instagram, Snapchat, or Flickr enable the constant upload, retrieval, and archiving of an unlimited number of digital images, and Twitter and Facebook tap into our words. These artworks remind us of data-mining

Figure 3.4
Douglas Bagnall. *Cloud Shape Classifier*. 2006. Installation view at MIC Toi Rerehiko, Auckland. Software, projection, electronic buttons. Image courtesy of the artist. [See color plate 6]

operations that are now performed by algorithms that were once considered to be the preserve of the human, from face-recognition software to accounting for emotions. Artist Zune Lee also introduces social encounters into the weather map, by wedding emotional and air quality data in the form of a game.

Weather Pong: A Game of Eco-mediation

Korean artist Zune Lee acts as a data hitchhiker and a social agent in his software-based art practice. Lee's game *Weather Pong* (2011) draws together air-quality data sourced from environmental sensors and social feelings about the weather as expressed on Twitter through live feeds. I played *Weather Pong* when it was installed at Auckland's Audio Foundation in 2011. By sliding a paddle along the base of the Ming-blue

Figure 3.5
Zune Lee. *Weather Pong*, v. 1.0. 2011. Audio Foundation, Auckland. Computer game program, joystick, LCD monitor.

projection screen with a gaming console controller, a colored ball ricochets around a screen full of spheres. The ball explodes bubbles of weather that represent ratios of pollutants and atmospheric conditions of sun, rain, and smog from commercial and citizen weather data streams. Floating bubble emoticons represent emotional states produced by weather that are data-mined from Twitter. Common idioms such as "I'm feeling under the weather" or "it's a happy, sunny day" are translated into six emotion bubbles. Lee transforms established application programming interfaces (APIs) from Synth-catch, a program for turning sentences into icons, for the analysis of human emotions. Positive emotions and healthy air quality encourage a tree to grow through the center of the screen. Negative emotions combined with NOx and CO_2 cause the tree to darken and wither.

As an act of hitchhiking, *Weather Pong* generates rhythms of data from sounds, shapes, and colors that connect our senses to weather. The screen is divided in half to compare two streams of weather and air quality data, including carbon dioxide and nitrogen dioxide levels from Auckland and from Seoul in version 1.0 of the work, which I played at the Audio Foundation. Color plays a fundamental role to create patterns in scientific visualization and in art: the 256 RGB colors in *Magnet*, the blue in *Most Blue Skies*, the red and green in *Irma* direct our attention, while the whimsical pastel tones of *Weather Pong* designed by Lee are decidedly unscientific. Still, retinal color effects in the brain generate a heightened reflexivity of our own perception, a vital dynamic that couples an "affect with an effect" (Massumi 2007, 14). The electronic xylophone-like sound designed by Changgyun Jung creates a gentle mood, punctuated with disturbing rattling sounds or base subsonic rumbles when negative properties or emotions are encountered, further associating the data sets with sound. The bubbles sometimes collide and form a new bubble state with an accompanying sound; for example, Fear and Fog combine to produce a Smog bubble, and Sad and Cloud fuse into a Fog bubble.

Weather Pong was later included in the group exhibition *The Weather Tunnel* in Beijing (2011), using the data sets from Auckland and Seoul. Seasonal "yellow storms" drift from China to the Korean peninsula, causing poor air quality and amplifying the politics of Lee's work when installed in Beijing. Fears about poor air quality and toxic rain for South Koreans came to the fore after the nuclear power plant breakdown in Japan caused by the 2011 earthquake and tsunami. Closer to home in Seoul, Lee is concerned about the air pollution caused by the excessive use of air conditioning units and the carbon emissions of the transport networks. Anxieties about Korea's air quality and related health issues are frequently expressed via online social communities such as Twitter. Lee's game operates as a social tool to bridge the gap between both human-qualitative modes of sensing weather phenomena and instrumental-quantitative data sets.

The Auckland live weather data for *Weather Pong* was sourced from Weather Underground, a website via which citizens can upload weather information from home weather stations. Weather Underground has operated since 1993 as a challenge to "the conventions around how weather is shared to the public" in order to bring weather forecasting to parts of the world that are underserviced by mainstream weather providers (Weather Underground, n.d.). At the other end of the spectrum, statisticians employed by large conglomerates, such as Google or Hollywood production houses, data-mine social media for commercial purposes. Nonprofessional users need the right training in computer science and statistics to obtain meaningful results from data-mining. Lee puts data-mining algorithms to ecopolitical use in *Weather Pong* in collaboration with software designers Inho Wohn and Chihyoung Shim, who were sponsored by Art Center Nabi in Seoul. Creative uses of data-mining techniques, such as *Weather Pong*, resist ubiquitous corporate surveillance, democratizing an elite medium to make it serve the community. Nothing is difficult about reading the weather or air quality in *Weather Pong*'s interface, so long as we concentrate on the ball, play, and listen. While playing the game, I felt a sense of agency over my weather world that defied immediate

Figure 3.6
F4 Collective (Susan Jowsey, Marcus Williams, and Jesse and Mercy Williams). *O-Tū-Kapua: My Personal Cloud*. 2016–2017. With New Zealand's National Institute of Water and Atmospheric Research (NIWA); Maree Sheehan, Claudio Aguayo, and his assistant, James Smith, from AUT; and Roy Davies, the CTO of Imersia.

logic. Game playing like this diffuses psychic fears around a real ecological threat by creating a dialogic space of encounter.

O-Tū-Kapua (*What Clouds See*)

Like *Weather Pong*, *O-Tū-Kapua* (2016–2017) is a participatory art project that connects science and the social world. Indigenous cosmologies and meteorology are drawn together to visualize local weather and air quality in Auckland. The project was developed for TEMP, a program of art/science and community assemblages in which artists and climate scientists brokered new artwork. *O-Tū-Kapua* was initially developed by the art collective F4 (Sue Jowsey, Marcus Williams, and their children, Jesse and Mercy Williams), who collaborated with a team of researchers from NIWA. Their goal was to investigate how weather data and air pollution information could be made meaningful for children. *My Personal Cloud*, an early phase of the project, included the composition of a waiata (Māori song) by Mercy Williams, a bilingual song writer. Mercy cocreated this "climate change waiata" with children from Prospect School and Te Kura Kaupapa

Māori o Hoanu Waititi. The *kura* (school) is an immersive Māori language school in Glen Eden in West Auckland. Māori sound composer and academic Maree Sheehan contributed the aural dimension to the mixed reality experience in a later part of the project. The haunting stories of Hauāuru (the West Wind), were composed using contemporary instruments and *taonga pūoro* (traditional Māori instruments), fused with the songs of the birds and insects that fill the air in the Waitakere Ranges.

The team was concerned with the relation between our internal senses and exterior weather as a culturally specific experience. They write: "The voluminous size and scale of clouds and their ethereal qualities were reconfigured through *My Personal Cloud*: cloud became something that fitted into the personal space of the child." (TEMP, n.d.). Dr. Josie Keelan, of the Ngāti Porou iwi, gifted the name *O-Tū-Kapua* for the project, which, loosely translated, means *what clouds see*. *My Personal Cloud* asks "how we inhabit the atmosphere, and conversely how it inhabits us" (TEMP, n.d.). A perspectival shift asks us to imagine the world from the above, wrapping us in living ancestor-clouds. For many Māori, *te mea*—"the things" or stuff of our cosmos—connects human and nonhuman elements in a bond of care. Systems of religion, power, and capital associated with colonization have systematically excluded Māori spiritual knowledge. *O-Tū-Kapua* expresses a counterflow to normative representations of weather within scientific parameters by infusing data with cultural forms of knowledge.

The project unfolded over several years in three stages: the first stage was to engage children with the invisible movements of weather by using different senses such as smell, taste, and touch. The atmosphere was linked to the children's own life experiences and cosmological understandings, rather than by imposing a Eurocentric version of the physical universe. Formal portraits of the *tamariki* (children) holding their clouds were videoed for one second to form an animated sequence. The waiata became an accompaniment to this film and an aerial cloudscape of children's personal clouds suspended in Te Uru gallery. The clouds, made from organic wool, were personalized and made tangible. The second stage, the *AirScience Pilot*, elicited the students' cultural perceptions of air and sky and then linked their insights to processes of observation in atmospheric and climate change science. Collections of data from particulate matter sensors were introduced to show how qualities of air are measured in science as one form of generating environmental knowledge.

The third stage of the project was the development of a mixed-reality project in which F4 and the NIWA scientists were joined by mobile education researcher Dr. Claudio Aguayo and his assistant, James Smith, from Auckland University of Technology (AUT), and Dr. Roy Davies of Imersia. *O-Tū-Kapua* (*What Clouds See*) eventually took the form of a physical and aural mixed-reality installation, designed for imaginative play using a marker-based interface. The physical installation takes the form of a forest; two-dimensional props, including stage-set-like trees, are gradually populated with flora and fauna produced by children. With a mobile phone held up to a marker, the augmented-reality interface comes alive, producing data in a fourth dimension linking city pollutants and weather data to the growth of the forest. When I visited the exhibition, the children around me painted and collaged their own pictures of colorful birds and insects to add to the installation. When they held up their mobile devices to particular markers, they discovered how wind speed, humidity and pollution levels effected the virtual tree in front of them. Air quality and climate science are folded into an experiential atmosphere rich with bush sounds and the strains of *taonga pūoro* in a sonic connection to the ancestors of sky and forest.

The interdisciplinary team of researchers chose to focus on children—the generation that will inherit environmental and social issues associated with a changing climate. F4 wrote: "Scientific discussions around the mechanisms, impacts, and options for adaptation predominantly exclude the input of children. Climate science is perceived to be beyond the scope of children, often categorized as dry in both subject and methods. We believe participatory projects such as this can introduce atmospheric science to children in a meaningful way, using imagery, language, music and other creative activities that enable them to creatively converse, question and understand climate science and our interdependence on the environment around us" (TEMP, n.d.). Sustained attention to the voice of children prizes open accepted routes of visualization in art and science. The bridging of knowledge between Indigenous values and mathematical data sets is crucial territory for visualization. The hackneyed separation of "prescientific" understandings of nature and scientific knowledge is very far from the truth, as Arendt observed (2006, 263). She challenges the prevalent idea in modern science that "we have come to live in a world that only scientists 'understand'" (ibid.). The generative collaboration of F4, NIWA, technology designers, and school children erodes the annexing of science from cultural life.

Critical questions about the relation between art and science are raised in data hitchhiking practices that ride on institutional meteorological data sets. Despite forming links with science organizations to use a wide range of data, the process of scientific collaboration often disappears from view in an art installation. When the complex negotiations with science organizations are made invisible, we are offered sensations yet left without a deeper understanding of how an artwork came into being. Art that obscures its scientific mechanisms can be likened to Ihde's insight about scientific visualization; for scientific depictions to convince, the instrumentation must withdraw so that the patterns can stand out more clearly (1998, 472). But why should the relationships with science organizations be foregrounded for art to perform affective-political operations? Artists are not bound by the demand in conventional weather mapping for an envisioner to make data readable within a defined field of signification. When artists forage for satellite signals and weather information from multinational companies or governments, they engage in a particular ethos of reuse of capital investment. An aesthetic politics emerges through the release of weather data into unforeseen assemblages.

Meteorological art redistributes knowledge and privileges a roving, embodied interaction with data. Mobile applications for accessing air quality and weather information in science and commerce also are increasingly personalized and adaptive. Yet the very lack of fixity of the weather when it appears in art implies the constant questioning of perception, human or machinic. The flickering color changes of Lausten's *Magnet* allow us to optically sense weather shifts rather than to defer to scientific interpretation of data. *Severe Tropical Storm 9301 Irma* unsettles the institutional framework for interpreting the weather map; *Most Blue Skies* mathematically works through a simple question of blueness; *Weather Pong* provides an outlet for social anxieties; and *O-Tū-Kapua* (*What Clouds See*) reveals that Indigenous, scientific, and children's weathers are never mutually exclusive. Far from Latour's description of a scientific visualization as an "immutable mobile" in which dissenters are forced to concede their positions, or Ihde's repeatable "gestalts," artists visualizations travel and change. Scientific visualizations tend to standardize representations of the atmospheric system, yet artworks imply that scientific mappings can only ever be understood as situational, rather than universal.