

Planetary Computerization and Media Ecologies

The programmability of the earth and its environments as operation-spaces activates distinct ways of approaching the planet as a modifiable object. However, the earth of *Program Earth* is not a stable object undergoing a certain modification. Instead, one could say that, from *Sputnik* to the multiplicity of networked sensors that have since developed, sensing technologies are involved in parsing and making present certain entities and capacities that are bound up in the relational project of programmability. The “earth,” as this discussion so far has suggested, is an entity that might be approached as both an antecedent object or datum as well as an entity in process and formed through modes of individuation and concrescence

that enable this entity to stabilize and have consistency—as a unit of relatedness, concern, observation, and experience. The planetary then describes processes of individuation and concrescence that in-form the potential of this entity, Earth, to take hold and be experienced in particular ways. Programmability is one way of characterizing a particular process of individuation and concrescence that activates the planet and its entities as an operation space.

Earthly observations can be generative of distinct engagements and relationships. As discussed earlier, *Earthrise* is typically discussed as sparking international environmental initiatives through a “Spaceship Earth” photographic perspective and a counterculture ethos that was simultaneously a sort of neoliberalism in the making.⁴⁹ A planetary perspective can at once prove to be limiting and enabling for environmental practices.⁵⁰ It can also be the basis for an “infrastructural globalism,” as Paul Edwards argues, that binds certain types of scientific practice together in the interest of understanding the planet as a discrete system.⁵¹

If the satellite view has largely been narrated as a project of making a global observation system and of seeing the earth as a whole object, then the more distributed monitoring performed by environmental sensors points to the ways in which the earth might be rendered not as one world, but as many. Here are multiple earths, in process, programmed and in operation, unfolding through distinct environmental conditions, sites of study, and responsive inhabitations. Where global observation systems might be working toward a planetary-scale project of knowing the earth as an entire system through (ideally) linked-up data sets,⁵² in contrast multiple earths are articulated through numerous distributed sensors that as currently implemented rarely form a “system of systems,” and more likely produce discrete and localized data sets for particular purposes. What “counts” as an environment—and Earth—then concresces in different ways in relation to the sensors sensing within distinct conditions.

The multiple “views” or “senses” that environmental sensors concretize might be approached through the machinic polyphony described by Félix Guattari in his discussion of “the age of planetary computerization.”⁵³ At the time of his writing, Guattari suggested there was an emerging age characterized by a “polyphony of machine voices along with human voices, with databanks, artificial intelligence, etc.” In addition, “New materials made to order by chemistry (plastic matters, new alloys, semi-conductors, etc.)” would take the place of previous materials. In this age, where time and experience were shifting, “the temporality put to work by microprocessors, enormous quantities of data and problems can be processed in miniscule periods of time.” With the new machinic subjectivities that he anticipated would arise, as well as the “indefinite remodeling of living forms” that would occur through “biological engineering,” he imagined there would be “a radical modification of the conditions of life on the planet, and as a consequence, all the ethological and imaginary references relating to it.”⁵⁴

Guattari captures a sense of how the earth and its inhabitants are remade through planetary computerization. In resonance with Simondon, Guattari identifies how the material, energetic, and machinic conditions that take hold and gain consistency become the basis both for remaking environments and remaking the human-machinic subjectivities that unfold in those environments.⁵⁵ In this sense, environments are not merely antecedent objects to be translated through informational devices, but rather are entities that concretize along with technologies. Computerization, in Guattari's view, becomes at once planetary and polyphonic, generating new living conditions, subjectivities, and imaginaries.

As the planet becomes a space of newly modified connections and relations, it also joins up and gives rise to new ecologies. McLuhan described *Sputnik* as a machine for generating ecologies.⁵⁶ The programmability that he identified as being key to this proto-remote-sensing technology was bound up with notions of what environments are and what it means to monitor and understand them. Contemporaneous with *Sputnik* and the rise of remote sensing, ecology shifted from an embedded field practice to an informational and even cybernetic undertaking, where the earth materialized as an object of management and programmability.

"Ecology" is a term that has multiple resonances and, as discussed throughout this study, also refers to informational or cybernetic management of environments as much as a philosophy of interconnectedness. Moreover, our post-World War II understanding of ecology is predominantly articulated through communication technologies, systems theories, and information science.⁵⁷ Donna Haraway has described how ecosystems, similar to immune systems or organisms, materialize through specific technoscientific practices that are informed by cybernetic logics. She therefore suggests a project of "probing the history and utility of the concept of the ecosystem."⁵⁸ Numerous texts—many of them referring to Haraway's early insights—engage with the question of how information theory and cybernetics have influenced the understanding and practice of ecology.⁵⁹ I draw on these informational and cybernetic approaches to ecology to consider how environmental processes and relations are not only increasingly studied through computational technology but also seen to be analogous to computational processes. Read through devices such as sensors and satellites, and assembled into networks and code, ecology is now a shifting entity that typically becomes visible—and manageable—as information. In this way, such ecologies inform our lived material, political, and ethical engagements, and they contribute to the scope of our environmental practices.

Clearly, in developing these articulations of environment and ecology, I am also situating this work in relation to research on *media* ecologies. "Media ecologies" as a term and area of media research has expanded from its former associations, where ecologies and environments might have been used rather interchangeably to discuss the at-times deterministic effects that media spaces were assumed to

have on subjects.⁶⁰ Newer work on media ecologies focuses on discussing the material-spatial conditions of media as part of an extended way of understanding what media are and the effects they have—encompassing but also extending beyond devices.⁶¹ More recent approaches to media ecologies also draw extensively on Guattari’s notion of the “three ecologies,” which makes the case for approaching ecologies across mental, socio-cultural and environmental realms.⁶² Within this space, some work on media ecologies goes so far as to even disavow the use of the term “environment” as a problematic term leaning toward unquestioned environmentalisms.⁶³

An important point of clarification that is stressed throughout *Program Earth* is that a practice of attending to the milieus of media technology does not automatically translate into an environmentalist encounter with media. While these are often discussed in the same space in relation to sensors for environmental monitoring, I make a point of understanding “environment” as not always already environmentalist in order to consider the distinct ways in which environmentalist practices and politics concreate in and through computation technologies as they become environmental. Environmentalism might then be articulated as a response to having monitored environments, for example, in relation to declining habitat or increasing temperatures. Or it might provide the impetus to monitor in the first place, where sensors are tuned to looking for patterns of change or disturbance, and where data is seen as the necessary resource for motivating political action.

Furthermore, “environmental media” as a term often signals a media-based focus on environmentalist topics and environmentalist modes of representation, or alternately points to the “greenness of media.” However, I discuss the becoming environmental of computation through the technoscientific processes that environmental sensors enable, rather than assume that this is automatically a project in sustainability.⁶⁴ Computational media unfolds not only through the capacities of devices but also through their environmental entanglements and effects, where material conditions such as soil and air together with circuits and screens generate concrete sensor-entities and experiences. With this focus, I am also building on my previous work that has attempted to draw out the environmental aspects of media by, on the one hand, attending to the atmospheric modalities and milieus of media and,⁶⁵ on the other hand, by considering the environmental effects of media in the form of electronic waste, which includes disposed gadgets as well as the extended spaces of mining, manufacturing, use, storage, recycling, and decay in and through which electronics circulate.⁶⁶ Computational technologies are constitutive of environments, have environmental effects, and also in-form environmentalist practices.

Program Earth then builds on research into media ecologies while making a distinction between environment as referring to *conditions* that form through multiple milieus, in the first instance, and to ecology as articulating the *connections*

that take shape within a milieu and across environments, in the second instance, as a way to develop sufficient analytical clarity to be able to discuss both the connections and the conditions whereby the environmental media of sensors take hold. By making this distinction, I am also working in relation to the descriptions of ecology made within scientific literature, which this study draws on in considering how computational sensors are used to study environmental change and advance engagements in citizen sensing.

As mentioned above, the earth in *Program Earth* is not a whole or singular figure. Instead, the earth articulated here is multiple in the ways in which it is put to work, and in the ways it is drawn into experiences of environmental change, practices of environmental citizenship, and optimizations of urban systems. In this sense, I look at this multiplicity not to celebrate the more-than-singular ways in which earth-ness is animated, but instead to consider how a multiplication and accumulation of programming-earth projects shifts the ways in which the practices and effects of digital media unfold. And one of the primary ways in which I take up these environmental sensing practices is by examining the modes of

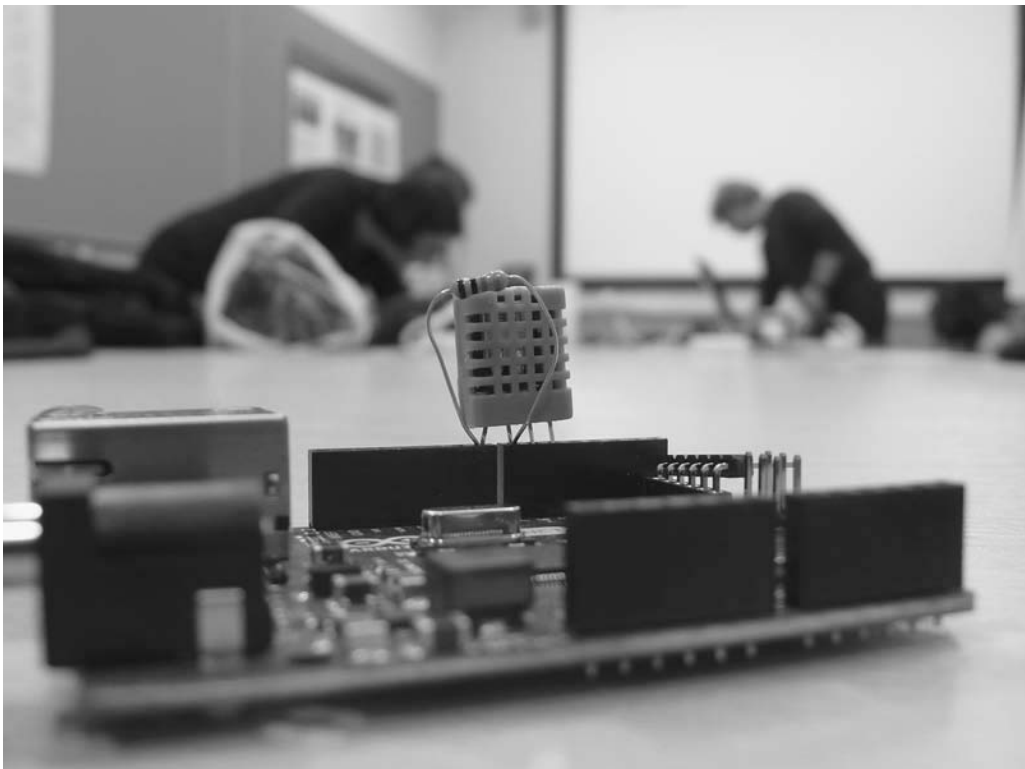


Figure 1.4. One basic example of a “DIY” sensor in the form of Arduino open-source electronics with a carbon monoxide (CO) sensor that would typically be found in a smoke detector. Assembled at a citizen-science workshop in London. Photograph by author.

citizen sensing that are expressed in and through the use of sensors. Since many environmental sensor applications are oriented toward understanding environmental change or managing environments, so too do the ways in which environments come to be articulated through sensing technologies have relevance for the types of environmental politics and citizenship that take hold along with these technologies.

FROM ENVIRONMENTAL SENSING TO CITIZEN SENSING

A key tool within ubiquitous computing, sensors are the technologies that make possible the distribution of computational logics beyond the screen and interface to spatial and environmental applications. While sensors have become embedded in everyday spaces and infrastructures, practices of monitoring and sensing environments have also migrated to participatory applications such as citizen sensing, where users of smart phones and networked devices are able to engage with DIY modes of environmental observation and data collection. Beyond monitoring ecological processes, sensors have then become key apparatuses within citizen-sensing projects that monitor air quality, radiation concentrations, noise levels, and more.

Yet how did the ostensibly technoscientific technology of environmental sensors migrate from computational and scientific uses to more everyday applications? And how effective are practices of citizen sensing in monitoring and addressing environmental issues and in giving rise to new modes of environmental awareness and practice? *Program Earth* examines the migration of environmental sensors from ecological research and commercial applications to a wider array of environmental and “citizen” engagements. By analyzing informational ways of understanding environments, I map the trajectory of the computational and informational approach to environments from ecological sensing applications to more citizen-focused undertakings, and to urban and infrastructural developments that join the objectives of sustainability, intelligent cities, and engaged citizens. I further identify the material, political, and spatial relationships that environmental sensor practices enable; and I ask how a particular version of the “environmental citizen” has become entangled within these relationships and practices. The becoming environmental of computation includes processes of making citizens *and* milieus.

From citizen science to participatory sensing, crowdsourcing, civic science, street science, DIY media, and citizen sensing, a number of widespread practices of environmental monitoring and data gathering are emerging that variously work through ways of democratizing the technoscientific tools and understandings of environments.⁶⁷ While these terms are used in different ways to stress the scientific, big data, or civic aspects of these practices, I work with the term “citizen sensing” in order to draw explicit attention to the ways in which computational

and mobile practices of environmental monitoring might be discussed as modes of citizen *sensing*, specifically.

Citizen-sensing practices have been described as making inventive contributions to both the research and development of technological tools, as well as to modes of environmental monitoring.⁶⁸ These practices range from the use of sensor data to complement other environmental observations, including remote-sensing; ubiquitous-computing approaches that often focus on the capacities and practices of sensor technologies to achieve efficiencies; and engagement with social or civic media projects that emphasize the ways in which social networking can mobilize collected data to influence policy and political action.⁶⁹ Citizen sensing as I am defining the practice for the purposes of this study encompasses or refers to those sensing activities that use computational sensing technologies in the form of smartphones, as well as mobile and low-cost electronic devices such as Arduino and Raspberry Pi, and online platforms to monitor and potentially act on environmental events through the collection of environmental data.⁷⁰ Such distribution of sensing capabilities across sensor networks and multiple mobile and individualized platforms has become a focused site for environmental and technological engagement.

Citizen-sensing projects are often closely related to citizen-science studies, but differ in the ways in which they seek to enable environmental practice through direct engagement with environmental monitoring technologies. Such citizen-sensing applications, similar to citizen-science, are frequently based on practices of individuals voluntarily tracking and monitoring everything from pollution levels to biodiversity counts.⁷¹ Citizen-science projects are even increasingly transforming into citizen-sensing projects, where digital devices equipped with sensors are used to monitor environments and gather data.

In some cases, sensor technologies have enabled more thorough practices of environmental monitoring and observation that have already been underway through citizen-science initiatives, as in counting and tagging biological activities. In other cases, the capacities of sensor technologies have facilitated more distributed and potentially more accurate collection of data, such as urban air or noise pollution. Some applications extend the scope of citizen sensing not only to encompass sensor data and use of smart phones but also to draw on remote sensing and mapping to enable the tracking of deforestation or animal movements. In still other instances, these mobile sensor applications have sparked new forms of democratic organization and communication about environmental issues by effectively crowdsourcing environmental observations in order to influence environmental policy and action.

Another reason for engaging with these practices as *sensing* practices is then to draw out the ways in which computational devices are at once sensing and actuating technologies, as well as modes for sensing and experiencing environments.

Citizen- or participatory-sensing projects often propose to create “shorter circuits” between environmental information and the observers of that information, and in this way technologists and environmental practitioners have suggested that a more direct line of environmental action may be possible.⁷² *Program Earth* specifically charts the ways in which citizen-sensing projects configure environmental practice through data gathering and sensing in order to offer a more in-depth understanding of how environmental practices and politics materialize in relation to observing technologies and communication networks.⁷³ I consider how environmental monitoring and citizen sensing consist not just of observations of environmental change but also of technical, political, and affective practices that are part of a complex ecology of sensing for environmental action.

What is typically activated in this diverse set of practices is a set of proposals for democratizing environmental engagement and developing other ways of doing environmental science and politics. Yet just as many new questions arise about the ways in which citizen engagement with environments and environmental concerns are in-formed with and through sensing technologies. By using the term “concern,” I am here specifically drawing on Whitehead’s discussion of concern as an “affective tone” drawn from objects and placed in the experiences of subjects.⁷⁴ The becoming environmental of computation includes these ways in which distinct monitoring practices and modes of reporting are enabled—and delimited—through environmental sensors, as well as the citizens and publics that would be activated and affected by these technologies and sensing practices.

Working across citizen-sensing projects that take the form of proposals, experiments, and established practices, *Program Earth* examines the ways in which the distributed and accessible capacities of computational sensors are meant to enable greater engagement with environmental issues. It asks: In what ways do computationally based citizen-sensing engagements influence modes of environmental participation? Citizen-sensing initiatives often depend upon forms of monitoring, reporting, managing, and even self-managing in order to establish environmental engagement. How might the practices of environmental citizens as data gatherers be advanced through a more intensive understanding of these modes of environmental and political practice?

SITUATING THE FIELD

From the Internet of Things to the “quantified self,” there is a new set of terms circulating that engage with the ubiquitous aspects of digital media. Within this overarching area there are specific studies that focus on the imagined futures of ubiquitous computing, the distributed and spatial qualities of wireless or pervasive digital technologies,⁷⁵ and the ways in which sensor hardware and software move computation out of the black box and into the environment.⁷⁶ New texts are also emerging that provide an overview or wide-ranging survey of ubiquitous

computing,⁷⁷ yet these collections often do not focus intensively on issues of environmental sensing and practice.⁷⁸ Other texts engage with the use of ubiquitous computing for social activism, for instance, but the focus on environmental topics is also less intensive.⁷⁹ These existing ubiquitous computing texts are useful in establishing context for this emerging area of computing, as well as participatory approaches to digital technology. However, I address sensors explicitly as *environmental sensor* technologies, a function that becomes more evident when devices are used for monitoring environments and collecting environmental data. And although the speculative aspects of computational sensors do influence this study, I especially focus on the ways in which sensors are actually being used and deployed.

Program Earth considers environmental sensing as a technological practice that spans environmental studies, digital culture and computation, the arts, and science and technology studies. As discussed above, the becoming environmental of computation includes considering not just how environments concreate along with individuals and objects but also how distributions of experience might be recast in and through environmental processes. Environmental sensing technologies open up new ways of approaching digital technology as material, processual, and more-than-human arrangements of experience and participation.

While there is comparatively less research within digital media studies that focuses specifically on the environmental articulations and capacities of sensors, there is a significant body of literature dealing with social media and the participatory aspects of digital devices, typically in the form of the mobile and online platforms.⁸⁰ Research into social and participatory media is a rapidly burgeoning field, where social media are often analyzed through considerations of alternative content generation, community formation, or social change,⁸¹ as well as the politics and practices of observation, control, and tactical intervention.⁸² This work forms an important reference point for understanding the rise in participatory engagements with digital media. However, *Program Earth* is situated somewhat obliquely to studies of participatory and social media, in that while it is focused on the political and participatory enablement of environmental sensing, it is primarily oriented toward more-than-human, environmental, and distributed analyses of how citizens and citizen-based engagements are expressed through this distinct set of technologies. At the same time, this research focuses on the ways in which computing has not only moved beyond screens to environments but also given rise to new imaginaries for how to program environments for digital functionality and participation.

Rather than focusing primarily on individual use or content generation for human-led manipulation of Internet- or screen-based media, I consider how environmental sensors variously articulate practices constitutive of citizenship in and through sensed environments that come into formation through an extended array of technologies and practices. Participation, as I engage with the concept and

practice, is also a more-than-human undertaking.⁸³ I investigate how machines, organisms, energy, networks, code, and atmospheres in-form how distributed and environmental computing materializes and operates. Taking up the more-than-human, machine-to-machine, and algorithmic operations of wireless sensor networks, *Program Earth* addresses the proliferation of environmental and computational entities that concretize and participate in wireless sensor networks.

While this research synthesizes and draws on emerging media theories that deal with ubiquitous and participatory computing applications, it also seeks to develop a new terrain for thinking through distributed sensing technologies as articulating distinct modalities of environmental politics and practices. This book makes the case for different approaches to “sensing” within digital media studies, arguing that distributions and processes of sensation might be more effectively understood by not simply collapsing sensation into fixed sensing categories such as sight or hearing. Environmental sensing technologies entail a transformation of the “objects” that are turned into information; to produce information is a technological intervention that generates distinct types of realities, rather than simply mirroring them. With these insights in mind, it is possible to move beyond the notion that environments are something “out there” to be studied and acted upon by citizen sensors with their sensing devices and instead to look specifically at how the spread of informational techniques co-constitute monitored environments and informed environmental citizens. I draw on the work of Stengers specifically as she discusses the philosophy of Whitehead to develop a constructivist approach to environmental sensors to suggest not that environments are “constructed” (in the sense of being concocted) through sensing technologies, but rather that distinct capacities for *feeling the real* are articulated through these monitoring practices.⁸⁴

It is important to note that in focusing on environmental sensing, *Program Earth* is working in a register that is not a phenomenological treatment of sense and sensation. In existing literature, sensemaking aspects of media technologies are often discussed through theories of mediation or individual attention and embodiment.⁸⁵ In related approaches, “sensing” is focused on a human subject and often rendered through theories of phenomenological or prosthetic engagement. The difference in this approach pertains to how environmental sensors are not simply providing access to new registers of information for established subjects but are changing the *subjects of experience* as well as the sensing relationships in which subjects are entangled and through which they act. Hence, vis-à-vis Whitehead’s notion of the superject, we could say that the *superjects of experience* are also changing. *Program Earth* works to develop new theories of sensing that do not rely on an a priori human-centric subject or mediated subject–object relationship. Sensing here is not primarily or exclusively about human modalities of sensing, but rather has to do with distributed formations and conjunctions of

experience across human and nonhuman sensing subjects, in and through environments. Sensing, in this respect, is understood as a multifaceted process of participating, individuating, and concurring.