The Becoming Environmental of Computation

From Citizen Sensing to Planetary Computerization

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Abstract: In citizen-sensing projects, more extensively and democratically gathered data are typically presented as "the reasons for measuring air pollution", since it is through collecting data that everything from enhanced participation in environmental issues to changes in policy are hoped to be achieved. The impetus to monitor and gather data is bound up with established (and emerging) processes of understanding environments as information-based problems. Within citizen-sensing projects, data are intended to be collected in ways that complement, reroute or even circumvent and challenge the usual institutions and practices that monitor environments and manage environmental data. Data are seen to enable modes of action that are meant to offer effective ways to respond to those problems. With more data, potentially more accurate data, and more extensively distributed data, environmental problems such as air pollution are anticipated to be more readily and effectively addressed. Data are intertwined with practices, responses to perceived problems, modes of materializing and evidencing problems, and proposals for political engagement. But how are air-quality data constituted, whether through expert or citizen practices? How do differing practices of environmental monitoring inform the character and quality of data gathered, as well as the possible trajectories and effects of those data? What are the instruments, relations, and experiences of air-quality data generated through these distinctive engagements with environments and technology? And in what ways do environments become computational through the use of low-cost air-pollution monitoring technologies? I consider how citizen-sensing practices that monitor air pollution experiment with the tactics and arrangements of environmental data.

Keywords: Citizen sensing; air pollution; environmental sensors; environmental data; creaturing.

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1. Introduction

In addressing the STS Italia conference theme of "sociotechnical environments", I am drawing in part on my research into environments, environmental sensors and the increasing instrumentation of the planet[1]. I take up this topic in my book, *Program Earth* (2016), which addresses the programmability of the planet by focusing on the becoming environmental of computation. I understand computation to include computationally enabled sensors that are distinct and yet shifting media formations that traverse hardware and software, silicon and glass, minerals and plastic, server farms and landfills, as well as the environments and entities that would be sensed. In other words, I am attending to the extended scope of computation that includes its environmental processes, materialities, and effects.

Through discussing specific instances where sensors are deployed for environmental study, citizen engagement, and urban sustainability across three areas of environmental sensing, from wild sensing to pollution sensing and urban sensing, I ask how sensor technologies are generating distinct ways of programming and concretizing environments and environmental relations. I further consider how sensors inform our engagements with environmental processes and politics, and in what ways we might engage with the "technicity" of environmental sensors to consider the possibility for other types of relations with these technologies[2].

Environments, as I develop the concept in *Program Earth*, are conjugations of subjects and superjects, following Whitehead, entities can be approached not as detached objects for our subjective sensing and contemplation, but rather as processes in and through which experience, environments, and subjects individuate, relate, and gain consistency (1929, 15 and 41; 1938, 94 and 112). "Environment" as a term has multiple resonances and genealogies. Within this space of examining ubiquitous computing and sensor networks, I consider specifically how environments inform the development of sensor technologies and how these technologies also contribute to new environmental conditions. Not only do computational technologies become environmental in distinct ways, the environments they populate are also in process.

Environment is not the ground or fundamental condition against which sensor technologies form, but rather develops with and through sensor technologies as they take hold and concresce in these contexts. Distinct environmental conditions settle and sediment along with these technologies as they gain a foothold. These processes involve not just the

[1] See Gabrys (2016). This text includes portions of an abbreviated reprint from *Program Earth*, courtesy of the University of Minnesota Press.

[2] For a more extensive discussion on technicity, see Simondon (1958, 152); Combes (2013, 60); Lamarre (2013, 92).

creation of the entities and environments that are mutually informed but also the generation of the relations that join up entities and environments.

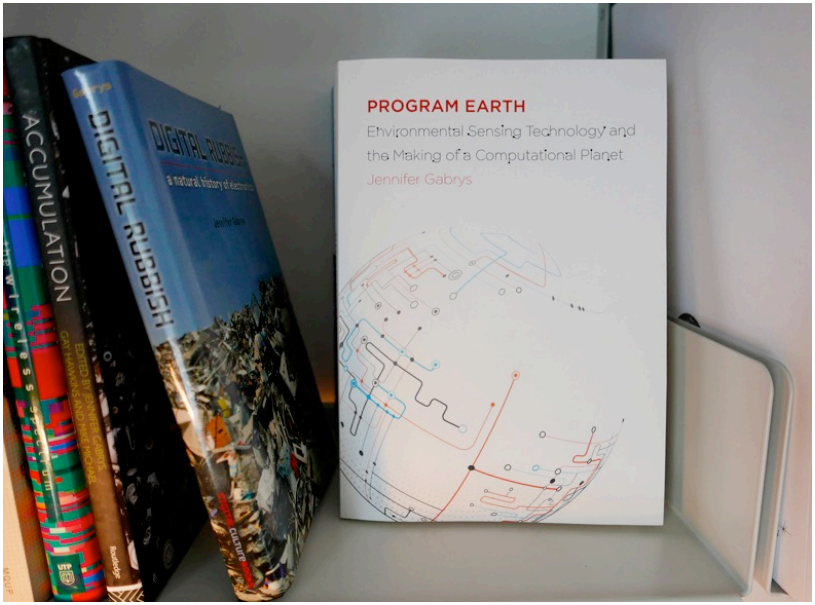

Fig. 1 – *Program Earth*, Jennifer Gabrys, 2016.

On one level, environmental sensors are input devices that facilitate monitoring, measuring, and computing. Yet on another level, environmental sensors can be described as engaged in processes of individuating by creating resonances within a milieu, where individual units or variables of temperature and light levels, for instance, are also operationalizing environments in order to become computable. Working across my *Program Earth* text and signaling toward the Citizen Sense research group's practice-based work on pollution sensing[3], in this article I specifically look at technological milieus and the creaturing of data in relation to air pollution sensing.

[3] For more information on the Citizen Sense research project, see citizensense.net.

2. Sensing Air, Creaturing Data

If you should find yourself standing outside the Hobgoblin Pub on New Cross Road in the Borough of Lewisham, London, you might notice a grayish-white box approximately two-and-a-half meters high scrawled with a faded and cascading line of graffiti. Wedged in the space between buildings and facing outward toward the road, the air vent and monitoring equipment at the top may be one of the few details that betray the purpose of this structure, which is to measure air quality at this fixed spot in London.

Fig. 2 – The New Cross Gate Air Quality station (Citizen Sense, 2013).

One of the stations in the London Air Quality Network (LAQN) that covers thirty-three boroughs, this monitoring station contributes to the hourly indexes of air quality and news of pollution "episodes" in London. Detecting sulfur dioxide (SO_2), particulate matter 10 and 2.5 (PM 10, PM 2.5), as well as nitrogen oxide (NO) and nitrogen dioxide (NO_2), the station generates data that indicate whether the UK is meeting EU air quality objectives for both short- and long-term emissions of pollutants[4]. The

[4] While all of these pollutants affect cardiovascular and pulmonary health, particulate matter (PM) is of particular concern. As the World Health Organization (WHO, 2014) notes in a fact sheet on air quality, "PM affects more people than any other pollutant. The major components of PM are sulfate, nitrates, am-

data also contribute to environmental science research and are managed and made available by the Environmental Research Group (ERG) at King's College London, where this network is managed and run.

Passersby may experience, in a potentially fleeting way, the connection between this station, the local air quality, and the data it generates, which typically circulate in spaces of environmental science and policy. The air quality data that are generated at this fixed site are black-boxed and located in spaces somewhat remote from experiences of air quality on the street. Air quality data are not typically present at the point of encounter with this station, but instead are located in more distant spaces of laboratories and servers, where data are gathered and processed to influence the management of environments and air quality.

In order to make air pollution data gathered by this station and the approximately one hundred other stations in the LAQN more accessible, King's ERG has designed a London Air app to allow people to observe emissions levels at key monitoring sites and to make inferences about their own personal exposure when passing through these sites. While this strategy moves toward making the data of fixed sites more accessible through an air quality app, the pollution that individuals experience in their everyday trajectories may be quite different than the types of pollution that are captured through fixed monitoring sites generating data that are averaged over set monitoring periods. The New Cross Road station, for instance, typically records an annual exceedance of NO_2 at this fixed point – a pollutant formed through combustion of fuel that is largely the result of high levels of automobile use in the city[5]. Yet all along New Cross Road individual moments and locations of exposure may give rise to a far different set of pollution "episodes", with much different consequences for urban dwellers in these areas.

Inevitably, the question arises as to how individuals may generate data about their own mobile exposure to air pollution, which is likely to differ from the fixed sites of the official monitoring stations. As discussed throughout this study, environmental monitoring is proliferating from a project undertaken by environmental scientists and governmental agencies to a practice in which DIY groups and citizen sensors are now en-

monia, sodium chloride, carbon, mineral dust and water. It consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air. The particles are identified according to their aerodynamic diameter, as either PM (particles with an aerodynamic diameter smaller than 10 μm) or PM (aerodynamic diameter smaller than 2.5 μm). The latter are more dangerous since, when inhaled, they may reach the peripheral regions of the bronchioles, and interfere with gas exchange inside the lungs." See WHO, "Air Quality and Health."

[5] The EU air quality objective (2008) indicates that there should be no more than 40 μm/m3 of NO2 per year. The New Cross Road station (in the borough of Lewisham) recorded 51 μm/m3 of NO2 in 2013. Also see the London Air Quality Network (LAQN) and the European Commission "Air Quality Standards".

gaged. Many recent citizen-sensing projects that deploy lower-cost digital sensors and smartphones have focused on monitoring air quality levels in ways that attempt to make environmental data more immediate and connected to experienced conditions. One of the primary ways in which such citizen-sensing projects have sprung up is through direct engagement with monitoring environmental pollution. While some citizen-sensing projects use the itinerant aspects of individual exposure to environmental pollution as a way to experiment with mobile-monitoring practices with which fixed sites of detection cannot compare, other projects, suggest that official or government data may not always be available or trusted, so that alternative data sources may be necessary in order to gauge exposure to pollutants of immediate concern.

Fig. 3 – DIY air pollution sensing (Citizen Sense, 2014).

Whether displaying pollution levels or developing platforms to make pollution information more readily available, many citizen-sensing pollution projects attempt to make the details of environmental pollution more instantaneous and actionable. An even more extensive range of pollution-sensing projects have turned up in this area, from devices that use low-cost electronics, including Speck (for PM 2.5 sensing) and AirBeam (for NOx sensing), as well as Citizen Sense kit using Shinyei PM 2.5 sensors. Citizen sensing is a strategy that often attempts to translate practices of monitoring pollution from the spaces of "expert" scientific and government oversight into practices and technologies that are available to a wider array of participants. As the EPA has noted in its work on surveying and assessing the rise in citizen-sensing practices and low-cost monitoring

equipment, air pollution monitoring is no longer confined just to official networks and the professional practices of scientists and technicians, but is proliferating into new types of uses that might, they anticipate, even begin to "supplement" regulatory approaches to air pollution. "New breakthroughs in sensor technology and inexpensive, portable methods", one U.S. EPA (2013, 2) report notes, "are now making it possible for anyone in the general public to measure air pollution and are expanding the reasons for measuring air pollution"[6]. With these citizen-sensing practices, data shift from having to meet a regulatory standard to ensure policy compliance to proliferating and indicating change, hence perhaps instigating different citizen-led actions.

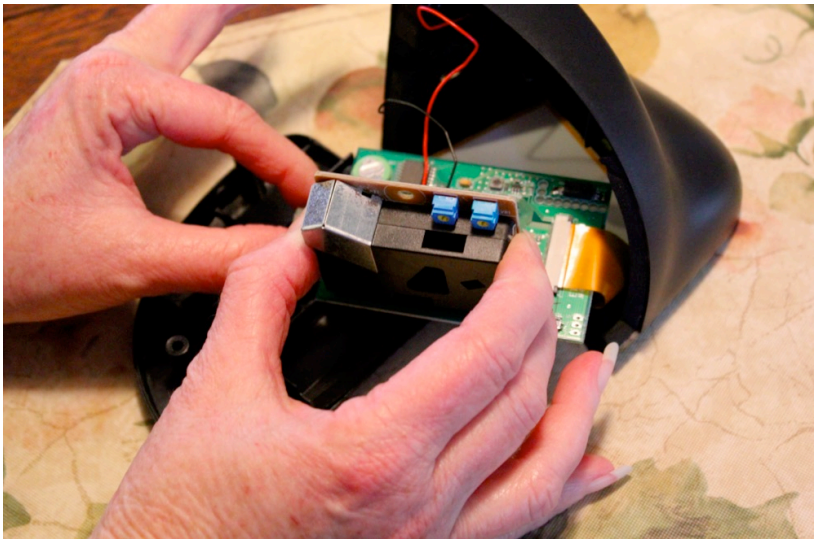

Fig. 4 – The PM 2.5 sensor (Citizen Sense, 2014).

In citizen-sensing projects, more extensively and democratically gathered data are typically presented as "the reasons for measuring air pollution", since it is through collecting data that everything from enhanced participation in environmental issues to changes in policy are hoped to be achieved. The impetus to monitor and gather data is bound up with established (and emerging) processes of understanding environments as information-based problems. Within citizen-sensing projects, data are intended to be collected in ways that complement, reroute, or even circumvent and challenge the usual institutions and practices that monitor envi-

[6] See also Snyder *et al.* (2013).

ronments and manage environmental data. Data are seen to enable modes of action that are meant to offer effective ways to respond to those problems. With more data, potentially more accurate data, and more extensively distributed data, environmental problems such as air pollution are intended to be more readily and effectively addressed. Data are intertwined with practices, responses to perceived problems, modes of materializing and evidencing problems, and anticipations of political engagement. But how are air quality data constituted, through expert or citizen practices? How do differing practices of environmental monitoring inform the character and quality of data gathered, as well as the possible trajectories and effects of those data? What are the instruments, relations, and experiences of air quality data generated through these distinctive engagements with environments and technology? And in what ways do environments become computational through the use of low-cost air pollution monitoring technologies?

In the process of monitoring air pollution, citizen-sensing practices experiment with the tactics and arrangements of environmental data. These monitoring experiments, however, are not just a matter of enabling "citizens" to use technology to collect data that might allow them to augment scientific studies or to act on their environments. Rather, as I suggest throughout *Program Earth,* computational-sensing technologies are bound up with the generation of new milieus, relations, entities, occasions, and interpretive registers of sensing. The *becoming environmental of computation* describes this process. Sensor-based engagements with environments do not simply detect external phenomena to be reported; rather, they bring together and give rise to experiencing entities and thereby actualize new arrangements of environmental sensing and data. The production of air quality data through environmental monitoring generates distinct subject-superject entities and occasions for generating and making sense of that data – as scientific facts, matters of concern, or even as inchoate patterns produced through unstable technologies or sporadic monitoring practices.

As a central point of focus, this lecture then crucially asks in what ways environmental sense data emerge not through universal categories or forms but as concrete entities – or *creatures* – that concresce through processes of subjects participating in environments and environmental events. "The actual world is a process", Whitehead writes, and this "process is the becoming of actual entities. Thus actual entities are creatures; they are also termed 'actual occasions'" (1929, 22). Actual entities are creatures, or lively meetings of entities that form routes of experience. In this sense, the process of gathering air pollution data might be identified as more than documenting static facts of air quality at any given time or place and instead be approached as a practice that gives rise to entities and modes of participation that transmit data in particular ways and along distinct vectors of environmental participation.

Working with this Whitehead-inspired analysis of how concrete enti-

ties of environmental data materialize through pollution sensing, I then consider how environmental-sensing projects are processes of what I call *creaturing data,* where the actual environmental entities that come together are creations that materialize through distinct ways of perceiving and participating in environments. These creatures may have scientific legitimacy. Or they may form as alternative modes of evidence presented in contestation of scientific fact. But in either or both capacities, they are *creaturely* rather than universal arrangements of data.

The point of attending to the creaturing of data is to at once draw attention to the concrete actual entities of data – even the "accidents" of data, as Whitehead would have it – and to take into account the "conditions" that give rise to and sustain these creatures of environmental data. Creatured data are not an abstract store of information or something to be coherently visualized, but rather are actual entities involved in the making of actual occasions and material processes. Data may typically appear to be the primary objective of environmental sensing projects, which focus on obtaining data to influence environmental policy and practices, but along the way the relations and material arrangements that data gathering sets in place begin to creature new entities that concresce through monitoring practices.

Fig. 5 – Air quality sensor prototype.

The general ethos of many DIY- and citizen-sensing projects has been that by enabling and democratizing the monitoring of local environments, it may also be possible to achieve increased engagement with environmental concerns. These projects test, experiment with, and mobilize alternative modes of environmental citizenship. Yet in what ways do practices of environmental monitoring with sensing devices give rise not just to experimental modes of participation and civic engagement but also to different modalities for experiencing environmental pollution through monitoring practices that generate air quality data? Within these projects, how does the experience and experiment of air pollution and air quality data become a site of political, as well as potentially affective, engagement? How do the creatures of environmental data become points of attachment for influencing and in-forming environmental concern and politics?

3. Citizen Data and Environments of Relevance

While in *Program Earth* I discuss a range of citizen sensing projects as a way to engage with these questions, I also take up these questions specifically discussing the creatures of data that could be seen to emerge within Citizen Sense research. Within this abbreviated discussion of the "pollution sensing" aspects of the Citizen Sense research project, I consider how the generation of citizen data became entangled with the creation of environments of relevance, which were required in order for citizen data to take hold and have effect. I take up a more extensive discussion of these aspects of the Citizen Sense research in collaboratively written project articles on citizen and collective forms of monitoring, and in an investigation of the "just good enough data" that citizen monitoring mobilized in order to make claims to policymakers and regulators[7]. But to briefly mention this Citizen Sense research work here, I would note that the processes of citizens gathering data through kit that we collaboratively developed did not only involve working with sensors to tune in to air and emissions. These processes also involved arranging data as evidence, putting together data stories that were ways of "figuring" the problems of air pollution and the worlds that might come together in order for this air pollution to register, and of forming extended social environments in and through which citizen data could gain a foothold and become relevant for addressing problems of air pollution.

As citizen sensing and citizen data collection practices demonstrate, defining what counts as air pollution is not always a straightforward matter. This is particular the case when attempting to establish evidence of

[7] For a more extensive discussion of these aspects of Citizen Sense research, see Pritchard and Gabrys (2016) and Gabrys, Pritchard and Barratt (2016).

harm or possible harm[8]. Institutional and governmental monitoring networks typically identify pollutants of concern in response to health research that provides evidence for levels of harm caused by particular pollutants. As part of the Global Burden of Disease 2010 study, outdoor air pollution was identified as a leading cause of death, contributing to heart, lung, and cardiopulmonary disease, which are now particularly linked to PM 2.5 exposure, which are also less evident as pollutants[9]. In many ways, health research influences environmental policy, which sets targets in relation to which monitoring networks set criteria for monitoring, as well as providing air quality forecasts, management, and mitigation.

While the impacts of air pollution on human health are one of the key motivators for establishing air quality standards, often the means of monitoring and enforcing these standards can miss the localized pollution experienced by individuals. Environmental and individual health are bound up with articulations of what does and does not count as a pollution *episode* and what may constitute an excessive level of pollutant *exposure*. Emissions of a certain pollutant at a given site in a city may be within an acceptable range, but individual exposure may vary considerably. Air, noise, and water pollution are local if distributed environmental disturbances that many urban dwellers experience on a regular basis, although for some more than others since sites of pollution are often concentrated in lower-income urban areas. Emissions and exposure mitigation have then been identified as two different ways in which to monitor and manage air quality: one addresses fixed sites and reductions of air pollutants; the other attends to how individuals may manage their individual experience to lessen air pollution exposure, such as monitoring and taking alternative routes through cities, although not necessarily attending to overall reductions of air pollutants.

Articulations of personal, urban, and environmental health shift across these different strategies for addressing air pollution. Practices of monitoring pollution at the citizen or individual level is a way to counter or re-

[8] For established limits for common pollutants, see the U.S. EPA National Ambient Air Quality Standards (NAAQS) Table (https://www.epa.gov/criteria-air-pollutants/naaqs-table) and the European Commission "Air Quality Standards". For a discussion of the ways in which legal disputes become entangled in establishing both the matters of fact and concern of air pollution, see Jasanoff (2010). For a discussion on how exposure and harm become increasingly difficult to link within newer regimes of chemical living, particularly in relation to indoor air quality, see Murphy (2006). For a forthcoming discussion on evidencing harm through citizen-sensing practices, see Gabrys (2017).

[9] Ambient PM pollution contributes to 3.2 million deaths annually, and there are increasing levels of heart disease, lung cancer, and cardiopulmonary disease in association with PM 2.5 exposure. See Lim et al. (2012). The WHO (2014) suggests that "exposure to air pollutants is largely beyond the control of individuals and requires action by public authorities at the national, regional, and even international levels."

dress the possible gaps in data, but there is more to these projects than this, since in mobilizing sensors to bring environmental monitoring into a more democratic, if often individual, set of engagements, new material-political actors, engagements, and experiments concresce – along with new political (im)possibilities. The question arises as to how data become relevant. Air pollution data might become relevant through health research that establishes high levels of morbidity due to particular air pollutants, or through scientific monitoring networks that identify pollutants exceeding accountable limits, or through concerns for certain environmental effects, from acid rain to eutrophication, which unfold with excessive levels of pollutants.

Relevance is a term that Whitehead uses to address the ways in which facts have purchase, and the "social environments" that are set in place in order for facts to mobilize distinct effects (1929, 203; cfr. Stengers 2011, 259). Relevance is a critical part of the process of creaturing, since creaturing involves the ways in which creativity is conditioned or brought into specific events and entities. The ways in which creatures gain a foothold, in other words, is an expression of relevance. Social environments are integral to the immanent processes that condition and give rise to creatures – they do not exist without the formation of creatures, and they continue to co-evolve as the situations in which creatures make "sense" and have effect.

Environments, as understood within Citizen Sense research and throughout *Program Earth*, are then at once an "object" of study as well as a mutually in-formed and coproduced relation through which monitoring practices and gathered data take hold and gain relevance. The relevance of air quality data is not determined through absolute criteria, since these criteria shift depending upon modes of governance, location, and more. If data are understood instead as perceptive entities, it then becomes possible to attend to how data are differently mobilized and concresce within and through practices.

Data in one context might have the status of facts, and in another context might galvanize a much different set of a/effects. As the U.S. EPA has expressed in its analysis of new modes of environmental monitoring, "types of data" and "types of uses" are interlinked (2013, 2-5). Data typically only become admissible for legal claims when gathered through specified scientific procedures and with quite precise (as well as expensive) instrumentation. There may also be situations in which data are "just good enough" for establishing that a pollution event is happening, for instance.[10] Yet it remains a relatively open question as to what the uses and effects of data gathered through citizen-sensing technologies might be, since these creatures have arguably not yet settled into entities for which relevance is expressible. In other words, how do citizen sensors undertake

[10] For a more extensive discussion of the concept and practice of "just good enough data", see Gabrys, Pritchard and Barratt (2016).

actions with and through air pollution sensing practices and data? Could it be that the environments of relevance for this data are still in formation? This is something that the Citizen Sense Data Stories attempt to work with and through, in order to understand not just environments of relevance on a descriptive level, but also to contribute to practice-based formations of such environments through citizen sensing engagements.

4. Conclusion

At this point, it might be easy enough to make a statement about the ways in which environmental monitoring technologies "construct" the air and the problem of air quality. While this inquiry works in a way parallel to constructivism, it also attempts, following Stengers, to think of constructivism not as a process of making *fictions,* but rather of making realities concresce and take hold – or gain a "foothold", (2011, 163-164, 518). Sensors are part of generative processes for making interpretative acts of sensation possible and for attending to environmental matters of concern in particular ways. The environments, arrangements, and practices that are bound up with how facts take hold and even potentially circulate with effect are then a critical part of any study into how expanded and differently constituted air pollution data and data-gathering practices might have relevance and be able to make claims upon that data to effect change.

This approach to constructivism is different from a poststructuralist rendering, since ideas and language do not *mediate* things, but rather things concresce as propositional effects (Stengers 2011, 252). As Whitehead notes, every fact must "propose the general character of the universe required for that fact" (1929, 11). Here is another aspect of *tuning,* which is not just a process of making particular modalities of sensing possible across subjects, environments, and experiences (cfr. Gabrys 2012), but also involves the tuning of facts and the conditions in which those facts have relevance. If facts require particular social environments in order to have relevance, this does not make them illusory (Whitehead 1929, 203; Stengers 2011, 259). Rather, it draws attention to the conditions needed for facts to have effect. In this way, facts are creatures, since, as Whitehead (1929, 20) elaborates:

> "Each fact is more than its forms, and each form 'participates' throughout the world of facts. The definiteness of fact is due to its forms; but the individual fact is a creature, and creativity is the ultimate behind all forms, inexplicable by forms, and conditioned by its creatures."

The creatures of facts – and data – constitute entities that bring worlds into being – and also require worlds for these processes to unfold. Sense data are productive of new environments, entities, and occasions

that make particular modalities of sensibility possible. A social environment then plays a formative part in conditioning and supporting creatures of fact and creatures of data[11]. These are creatures of data because they are involved in creative processes in bringing sensing to possibility and of in-forming the environments where these modes of sensing have relevance.

A process of creaturing data then attends to the ways in which data are not fixed objects gathered through universal criteria but instead are entities through which forms and practices emerge as creatures, and through creaturely processes. As discussed throughout *Program Earth*, perceiving subject-superjects combine as *feeling* entities through actual occasions. These entities might otherwise be termed creatures, since they are formations of conditioned creativity. Furthermore, the "datum", as Whitehead discusses it, is not simply an external array of objects awaiting conceptual classification by a human subject. Instead, the datum is that which subject-superjects feel, and through this experiencing (and so processing and transforming) the datum, generate actual entities, or creatures.

Data are always felt and experienced by and as creatures, which through feeling further give rise to distinct forms of data. A process of transforming the datum into felt experience is a process of creaturing data because what issues through this process are subjects-superjects involved in processes of being and becoming creatures. Perhaps in the most concisely stated version of this insight, Whitehead writes, "An actual entity is an act of experience" (1929, 68). Feeling the datum is a process of transforming the datum into experience, which concresces as an actual entity or creature. Creaturing is then the description of this process of *feeling the datum,* where creatures are the actual entities formed through creaturing the datum.

If we consider the "data" that digital sensors generate, then these devices might be understood less as technologies for gathering (particularly quantitative) data and more as technologies for processing, transforming, and creaturing data – as a felt form of the datum. While it may be easy enough to query the assertion that more data and more democratically gathered data might lead to action and engagement, an approach to creaturing data suggests that it might be relevant to attend to the ways in which data are taken up, felt, experienced, taken into account, gain relevance, and attain "power" as the process whereby particular perceptions

[11] As Whitehead notes: "The data upon which the subject passes judgment are themselves components conditioning the character of the judging subject. It follows that any presupposition as to the character of the experiencing subject also implies a general presupposition as to the social environment providing the display for that subject. In other words, a species of subject requires a species of data as its preliminary phase of concrescence... The species of data requisite for the presumed judging subject presupposes an environment of a certain social character" (1929, 203).

or modes of prehension involve or prevail over others (Whitehead 1929, 219). These processes require the formation of social environments in order for data to have effect.

Why is this important? Because on a concrete level in order for citizen-generated data to be taken seriously and to inform environmental policy and politics, it is necessary to consider the infrastructures, environments and practices that are bound up with the creaturing of data in order to understand how to make citizen-generated data (among other forms of data) relevant in ways that can effect change. In other words, this requires tuning our attention to which modes of experience count, and for which purposes. Citizen-sensing practices are in-formation as experimental practices that test not just how environmental monitoring data might be differently gathered but also how such data might be mobilized within distinct environments of relevance, and to what (political) a/effect. Within this space, the modes and practices of data – the creaturely entities in and through which data manifest and give rise to worlds – are arguably an area yet to be fully explored, since data are so frequently presented as the abstract and dematerialized evidence of environmental fact.

In this context, what does it mean to "sense" or experience air pollution with computational sensors? Monitoring air pollution with digital sensors is not just a way of obtaining a "result" or fact about a particular environment but is also about the ways in which data are creatured and mobilized, the social environments that concretize and allow those facts to have relevance, and the additional attendant data practices that might come together to generate a/effects. Creaturing data is an approach that asks how we might consider much more than the "facts" gathered, since the extended social environments, practices, and speculative relations required to bring facts into a space of relevance are crucial to the creatures of data that materialize. Creaturing data is a way of attending to the processing and transforming of environmental data. This is not simply a matter of attending to the extended capacities of generating data but instead involves considering the creatures of data, the entities and situations that form and take hold, whether to solidify, experiment with, or change environmental practices and politics. As Whitehead (1929, 50) writes:

> "We find ourselves in a buzzing world, amid a democracy of fellow creatures; whereas, under some disguise or other, orthodox philosophy can only introduce us to solitary substances, each enjoying an illusory experience".

These creatures, as Whitehead (following James) has reminded us, then settle into "a democracy of fellow creatures," where the shared experiences of air, pollution, and possibilities for engagement might even bring us into inventive modes of solidarity.

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