

ADVANCED REVIEW

The substance of climate: Material approaches to nature under environmental change

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Climate change is at once immediately tangible and embodied—in hurricanes, droughts, and the expansion of tick and mosquito habitats, for example—and almost unimaginable from a human scale. Climate encourages us to think expansively, in terms of millennia, geological epochs, systems and patterns earthly in scope. Climate, through material and cultural processes, connects people to weather and the environment, particularly in timescales beyond the human lifetime—though some changes occur rapidly, visibly, and spectacularly. This review seeks to understand how people mediate between climate change at once lived and unfathomable. I propose that people do this through interactions with nature as material objects and earthly processes. That is, there is a substance to climate that is sometimes erased from abstract models and political debates. This article considers the substance of climate through three analytical frames: (a) matter and substance, (b) lively nonhuman nature, and (c) experience and embodiment in science and policy. The materiality of climate allows us to consider the scientific and environmental impacts of climate change immediately alongside the power dynamics that enable and can solve this problem.

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1 | INTRODUCTION

Climate change is a set of human engagements with the environment, engagement often violent and oblivious, but engagements nonetheless. These engagements are not only conceptual but also material, sensory interactions with substances around us. For example, in the image above, people stand on ice, with gear on sledges. The ice is a substance of climate—a material with physical properties as well as less tangible signals and effects that require experience to understand. When do the cracks denote easy passage or danger for the people standing there? When does the melting ice denote opportunity or danger for larger, more distant communities? These substances affect daily life in simple terms as well as reflect the ethical arrangements we make. “How does it feel to change the climate in sensory, rather than moral terms?,” Hughes asks, noting additionally that “feeling connotes tactile experiences as well as ethical dilemmas” (2017, p. 18). While broad scale abstractions are necessary conditions for understanding planetary effects, ethics and materiality converge under conditions of anthropogenic environmental degradation.

Feminist and science and technology studies (STS) scholars have begun to pursue lines of inquiry under the umbrella of “new materialisms” (Coole & Frost, 2010, see also Hird, 2009, Hird & Roberts, 2011, Irni, 2013, Kirby & Wilson, 2011, Willey, 2016). New materialisms scholarship attempts to bring back the differences wrought by things in the world into their analyses of power. Some new materialisms scholars take relationships between beings and things (and the gray areas between beings and things) as formed and affected by material realities, opening up new possibilities for thinking about ethics, politics, experience, and agency. Others fit questions about material relationships into the broader domain of posthumanism, which re-entangles human thought into the world and interactions which shape it (Grusin, 2015; Wolfe, 2010). Approaching climate change through the lens of new materialisms brings together the two dominant frames of global warming: that of power and politics on one hand and of tangible environmental impacts on the other. This review brings these ideas into conversation with transdisciplinary scholarship on climate change, considering how these approaches can illuminate analyses of climate change as it is sensed, experienced, measured, and acted upon.

This review will skate around the “ontological turn”—the study of how people and groups make worlds and worldviews—that has been productive for many of my colleagues in anthropology, STS, and other fields, for two reasons. One, my sense is that we have approached the end of this turn, and a revitalized attention to materialism is what, in my opinion, is the most significant contribution. Second, I take seriously the critique that the ontological turn is a repackaging—or appropriation—of ideas previously articulated by other thinkers, particularly indigenous scholars (Todd, 2016). Indigenous worldviews and analytic frameworks help us understand that “indigenous standpoints never forgot the interrelatedness of all things” (TallBear, 2017, see also Ahmed, 2008, Todd, 2016). Instead of using an ontological approach, my analysis aligns with Sandra Harding's in that we live in a “world of sciences” where multiple epistemologies inform and strengthen each other (2011, p. 9).

By focusing on the animations and engagements between subjects and objects in the world, this review seeks to ground encounters with substantive nature as elemental to understanding and responding to climate change. Therefore, “substance” is my primary analytic. “Matter” and “material” can be part of substances, but they contain a concrete object-ness, while substance suggests things within, surrounding, or supporting objects, beings, and things. This article considers the substance of climate through three analytical frames: (a) matter and substance, (b) lively nonhuman nature, and (c) experience and embodiment in science and policy. Through the work analyzed in each frame, this article seeks to explore the gap between climate in the realm of human experience and that of the more conceptual understandings of climate, beyond the scale of the human.

2 | MATTER AND SUBSTANCE

In modern, Western, scientific conceptions, nature around us, particularly that which is nonliving, is often depicted as blank, a stage, or passively receiving input from more agentive subjects, usually humans. This frame includes literature that challenges that supposition, in which earthly elements and nonliving nature are taken seriously and foregrounded as part of the action of climate change. Ice, air, gold, rocks, and other elemental matter interact with, shape, influence, and alter the environment in concert with anthropogenic climate change. In this frame, I first review texts that take a broad approach to the material nature of climate change, followed by a series of examples of specific substances of climate analyzed to bridge the gap between the particular and the unimaginable in climate change.

Timothy Morton (2013) includes global warming as an example of one of his “hyperobjects,” a thing “massively distributed in time and space relative to humans” (p. 1), which disrupts the conventional nature/ culture arrangements we have designed for ourselves in recent centuries. He elaborates that “hyperobjects force us to acknowledge the immanence of thinking to the physical” (p. 3), noting that while global warming cannot be discretely sensed, it can be “thought and computed” (p. 3). The substantive nature of weather has changed with anthropogenic climate change; Morton suggests that “what climate change has done is shift the weather from accidental to substantial” (p. 102). While weather phenomena have always been sensory experiences, the discourse, imaging, and projections of climate change have, to Morton, rendered a new weight upon the weather: climate is no longer a mere setting, but a story in and of itself. Boulton (2016) considers how Morton's hyperobject theory repositions climate narratives, suggesting that Morton's work provides a “powerful depiction of human vulnerability,” one that destabilizes humanity's sense of their very existence (p. 781). To Morton, that vulnerability is the substance of climate, at a human, experiential scale.

Matter, and matter's component elements, are easily imagined as foundational, true, and pure. However, material-discursive practices form these simple things as much as they form complex objects. As Barad explains in her exposition of agential realism, “matter is substance in its intra-active becoming—not a thing but a doing, a congealing of agency.” (2007, p. 151). That is, matter is a physical state of in-between-ness formed through observation and relationship. Substance can also be impetus for transgression or fetish and contains histories along with senses of place; Taussig calls these worlds made through substances “the world of ‘immanence’” (2009, p. 314). Tuana, analyzing Hurricane Katrina, suggests that these

interactions form “viscous porosity,” in which the built environment, human bodies, and a powerful weather phenomenon interact to create a catastrophe (2008). Substance, materiality, and matter evoke related affects and meanings, helping us consider difference ways for thinking about what it means to exist.

Matter can also refer to or contain liveliness, or more aptly, vibrancy, a concept examined in depth by Jane Bennett, implicitly extending a long, complex interest in vitality (2009). Bennett explains her analytical framework of vibrant matter as a “shift from the language of epistemology to that of ontology, from a focus on an elusive recalcitrance hovering between immanence and transcendence (the absolute) to an active, earthly, not-quite-human capaciousness (vibrant matter)” (2010, p. 3). Like Latour’s actants (2004), vibrant matter acknowledges that agency is not solely the domain of the humans and animals, nor are people and their *animalia* kin the only things capable of operating with intention. What distinguishes Bennett’s and Latour’s nonhuman actants is Bennett’s attention to vibrancy, in which substances hum with constant protentional instead of only at the moment of interaction.

That things are connected to words, ideas, and discourse is not new. Benjamin’s work on mimesis, particularly “thought-figures” takes us through these connections in some form (Benjamin & Tarnowski, 1979, original 1933, see also Taussig, 1993). In *Water and Dreams*, Bachelard performs an early take on materiality (1983, original 1942). Writing of a “material imagination,” he notes that poets focusing on a classical element (earth, water, fire, and wind) bely a particular type of intimacy with that substance that is materially different from a poet relying on another element (pp. 5–6). Bachelard’s analysis throughout this book, then, centres on “water thinking” in various forms, such as feminine and violent.

“Water thinking” persists today. For example, in contrast to “flat,” two-dimensional, terrestrial materialism, oceanic thinking insists on considering volume and depth, literal fluidity (Steinberg & Peters, 2015). The sea’s three-dimensionality and its “turbulent materiality” help us consider things and objects and the politics they contain (p. 247). Here, “oceanic thinking” links together the physicality of the ocean, the material effects of climate change, and the human actions and responses that can cause or ameliorate environmental degradation.

Frozen water—ice, in the form of sea ice, glaciers, and ice sheets—has a pervasive, insistent materiality that can trigger disaster to local communities and ecosystems (Carey, 2010), connote indigenous knowledge of and relationships to changing, risky landscapes (Cruikshank, 2014), and engage epistemologically but also sensorially with scientific experts (O’Reilly, 2016). Ice changes state and form, which means that local, indigenous, and scientific experts value knowledge of the substance, including its general behavior along with the skill to identify atypical, potentially climate-related change.

Air and what happens to it—that is, weather—is a lived, tangible experience of climate. According to Ingold, air is “an essential material constituent of the inhabited world” which is often overlooked in the anthropological twins of materiality, landscape and artifacts (2010, p. S132). Polluted air becomes another medium for understanding and experiencing environmental degradation. To Choy, air becomes substantial—becomes substantiated—as it “muddies the distinction between subjects and environments, and between subjects” (2011, p. 157). Polluted air in megacities, in Adey’s analysis, is a marker and a medium of inequality and broader discourses about security (2013). Atmosphere—in a physical sense as well as the connotation of moods—affects beings and relationships as it shifts or sets in (Adams-Hutcheson, 2017; Mason, 2018). Embodying and working with, through, and against air, as well as the airborne traces of industry, biology, and wind patterns, is as simple and as unavoidable as breathing.

Considering stone, Raffles asks, “what is writing culture when the object is neither human nor animal nor “multispecies” nor amenable to flattening into a network or assemblage, and yet is entirely inseparable from life itself, is in fact, life itself, and correspondingly, pre-, post-, necessary to, indifferent to, and transcendent of the human scale?” (2012, p. 527). These nonliving-but-life-itself objects, defying easily anthropomorphizing categories, require us to think differently about attention and analysis. Cohen (2015) also takes up stone, from the perspective of writing stone stories in the Middle Ages, noting that “the ecological project of thinking beyond anthropocentricity requires enlarged temporal and geological scales” (p. 9). Stones can readily transport humans across these scales, which Cohen calls “a provocation to cross-ontological fellowship” (p. 8).

Waste, as it piles up from increasing consumption and disposability, are material remnants of human lives and industry. Hecht, writing about the toxic remnants of a uranium mine in Gabon, notices that waste is an indicator of accelerating pollution that marks the Anthropocene, and in extension, climate change. “The materials that power such acceleration do not disappear—” Hecht notes, “not even when they explode. They change form and scale, but they are still there, some more noxious than ever for our species (and others) (Hecht, 2018, p. 132). Literal materials, waste is formed by the forgotten traces of our lives and continues to impact the environment.

Things enable human knowledge and industry. Interacting with people and their work can transform chemicals, objects, and elements into waste, pollution, or commodities, as Günel explains using the case of carbon capture and storage, even when coping with the transformations of substance along supply chains, infrastructures, and logistics networks (2016). Ice cores, along with their scientist translators, produce history, visions of the future, and even time itself (Antonello & Carey 2017; Salazar, 2018). Understanding aquifers requires “a four-dimensional imaginary that simultaneously consider

[s] multidirectional pressures and converging and diverging movements, all in flux due to the passage of time” (Ballestero, 2016, p. 49). Imbuing things with knowledge and labor—or producing new things with knowledge and labour—makes climate change visible, measurable, and actionable.

Ways of thinking about climate are inspired by the material world around us. Considering the disbelief of climate change among rural Bangladeshis, Khan examines Islamic cosmology and its relation to environmental opinions. “It would seem that dogs and *chauras* [Muslim farmers] are fated insofar as they belong to this earth,” she writes, “held together by a soil that disintegrates and disperses. But what is left unsaid is that although the earth breaks, it reconstitutes” (2014a, p. 262). In this case, the relationship with soil, in the shifting, eroding land around and in the Jamuna River, is a marker of environmental change, but not one of incessant environmental degradation. One non-governmental organization (NGO) official she met scoffed at the expert advice they had been given to avoid planting quick-growing eucalyptus trees in the silt islands in the Jamuna River because the trees consumed too much water, calling it “poisonous knowledge to keep the poor down” (p. 261). *Chaura* cosmologies, along with the continually shifting soil beneath homes and feet, makes climate knowledge that is mostly generated from faraway places on stable ground unbelievable. Here, the soil proves and disproves claims and authority.

Elements, materials, and things form much of the substance of climate. Their substance is specific, not general, and this specificity, including how it interacts with humans and the environment, makes climate change palpable and comprehensive.

3 | VITAL NATURE

Life is a substance of climate, a substance capable of embodying environmental change. Animated nature, sharing life in common with humans, is both easier to imagine as affecting the world around it than inanimate objects and easier to ascribe anthropomorphic traits to. Climate change can accelerate extinctions and reduce biodiversity: a flourishing, lively planet is contingent on continued habitability for a wide assortment of species. While matter of all sorts can contain vitality, I consider life a separate category because liveliness is a temporary, limited state, always able to be lost. This section investigates theoretical approaches to life before analyzing examples of nonhuman beings interacting with a changing climate.

Life can be considered as “immanence” which is imbued in material things (Deleuze, 1997). Living, Jullien clarifies, is the process of “feeding one's life,” or vital nourishment (2007). While Bennett (2009) extends vitality to matter, and this helps us clarify analytical approaches to matter as such, for the purposes of this review, I separate nonliving and living (or about to live, or once lived) forms of nature. This division is neither neat nor easily cleaved. Chen's work on animacies helps articulate this challenge, particularly “how the fragile division between animate and inanimate—that is, beyond human and animal—is relentlessly produced and policed and maps important political consequences of that distinction” (2012, p. 2). Animacies are also forged along intimacies, as the byproducts of our industries and efforts continue to dwell alongside us (Weston, 2016). Nonhuman forms of life can be understood as impressions, energies, passions, and in relation with other species, including humans. These living nonhumans experience and, through some of their behaviors, articulate and adapt to anthropogenic climate change. Understanding their lives provides a fuller account of what it means to live with environmental degradation.

Before we move into the domain of life as a substance of climate, consider how the substances, elements, and objects above have become interpolated into the liveliness of nature. Substance signals to life, human and beyond, and becomes part of it. For example carbon takes on “biosemiotic meaning” as it is metabolized by society (Szerszynski, 2010). Waves are historically gendered as female (and therefore human) (Helmreich, 2017). Szerszynski remarks “the living organism thus has a boundary in the way inanimate objects do not; it persists by maintaining a boundary and a differential relationship between inside and outside through the exchange of matter, energy, and information across that boundary. Metabolism thus has an intrinsic relationship to the living organism and the biological and the semiotic emerge in the same gesture” (2010, pp. 12–13). However, the living organism, enacted through metabolism, also is subject to various interpretations, gazes, knowledge practices, and power differentials (Mol, 2002). Forms of life sense and know, as Hayward suggests; species to her are “impressions” and “sensuous responses” as they seek to understand and interact with the world around them (Hayward, 2010).

Lingis uses “passions” as a trope of vitalism and animation for living and nonliving entities. He writes,

A living organism is a dense and self-maintaining plenum. Out of the energies it assimilates from its environment it generates forces in excess of what it needs to adjust to that environment and compensate for the intermittent and superficial lacks produced by evaporation and fuel consumption. This discharges of these superabundant forces are felt in passions. But the environment itself is full of free and nonteleological energies—trade winds and storms, oceans streaming over three-fourths of the planet, drifting continental plates, cordilleras of the deep that erupt in volcanic explosions, and miles-deep glaciers piled up on Antarctica that flow into the sea and break off in bobbling icemountains (2000, p. 2).

Lingis' "energies" and "passions" suggest an emotive, empathetic layer radiating around our environment, akin to light wave and electromagnetic forces. He pictures relationality among different things as occurring in these energetic fields around them.

Ingold (2000) also considers the distinctions between "things" and "beings" noting that nonhumans are often named "living things" while our species are called "human beings." He elaborates by suggesting that "if life is tantamount to being, then we have to regard the organism not so much as a living thing than as the material embodiment of a certain way of being alive" (p. 89). Extending this line of thought, Alaimo attends to the ethical and political formations that emerge when we undertake "emphasizing the material interconnections of human corporeality with the more-than-human world" (2010, p. 2). Forms of life, then, are forms of material embodiment, and embodiment encompasses more than individual bodies.

Studies of human engagement with nonhuman forms of life have a long history. Typically a nonhuman symbol of cultural and environmental meaning (e.g., Harris, 1966), animals represent human livelihood and organized community life. Evans-Pritchard extended this in *The Nuer: A description of the modes of livelihood and political institutions of a Nilotic people* (1940), writing about the Nuer people's "engrossment" with cattle, noting that "the only labour in which they delight is care of cattle" (p. 16). Evans-Pritchard sometimes veers into ecological anthropology with a discussion of the Nuer's "symbiotic" relationship with cattle, but then traces out a cattle-Nuer ontology, ultimately claiming that "their social idiom is a bovine idiom" (p. 19). That the Nuer cannot be thought of apart from cattle marks a signpost that significantly extends the recent wave of multispecies and animal studies (e.g., see Haraway, 2008; Kirksey & Helmreich, 2010; Parreñas, 2018; Waldau, 2013; Wolfe, 2003).

Environmental degradation, including climate change, can affect the very composition of individual bodies as well as populations and ecological communities. Life and liveliness are not settled categories, particularly when considering mutation, biotechnology, and ongoing exploration at the expanding edges of habitability and human observation (Helmreich, 2009, 2015; Orlove, Lazrus, Hovelsrud, & Giannini, 2014). These lives are bound together with other living beings as well as non-living objects and the amorphous "landscape." Working closely with the ideas of Deleuze and Guattari, Ogden (2011) examines how gators, mangroves, and humans across history form the Everglades in Florida, providing a close analysis of an enlivened landscape. Tsing (2015) decentres human exceptionalism by showing an assemblage woven of matsutake, pine, oaks, and the people moving within. Life experiencing climate change, obviously, can signify death, including the death of nature itself. As Khan writes of the Jamuna River in Bangladesh and observations people make elsewhere, "the intimidation of the death of nature acquires its particular distinction of allowing one to perceive climate change" (2014b, p. 289). The specter of death is an important discursive concept and material experience in a changing environment.

Understanding environmental change in nonhuman forms of life involves trying to learn the language of the others, the signals, codes, and gestures performed outside our ability to comprehend (Alaimo, 2016; Haraway, 2016). Kohn calls these "trans-species pidgins," and notes the limitations and opportunities brought about by material and spiritual forms (2013). Raffles elaborates, "this isn't merely a struggle over what the animal means; it is a struggle over the meaning of the animals themselves" (2010, p. 197). This struggle necessitates resisting the impulse to reflect humanity onto other species and also insists on emphasizing our shared experiences of life on Earth. For example, Raffles describes the micro-soundscapes produced by beetles and other insects in the American Southwest's piñon pines: "more than just the sound of life in trees, the soundscape is the soundtrack to an epidemic" (p. 329). The tree-borne insect population is in disequilibrium, not only responding to anthropogenic global warming but also hastening it, as the beetles chew up the trees, releasing more carbon back into our planet's system.

Researchers have produced close accounts of life and the experience of environmental and climate change, including considerations of the interaction of plants with urban space and people (Hartigan, 2015), the violent world-making of botanical collecting during colonization (Schiebinger, 2004), the interaction of vector-borne disease as a historical pivot (Mitchell, 2002), the intimate affections of coming to care for leaf bugs in Chernobyl (Schrader, 2015), and extremophile Antarctic microbial bioprospecting and their promise of patents and geopolitical discord (Salazar, 2017). These accounts attempt to examine change at their scale of existence, an emic methodology that orients the researcher to the forms of life they examine. Along with the humanities and social science research described here, natural and physical scientists produce knowledge along multiple scales, from the "scale of existence" through the vantage point of the global as a means for comprehending and predicting current and future environmental change.

This analytic frame has focused on scholarly work that attempts to understand nonhuman forms of life apart from and entangled with human life, that broaden animal experiences of climate change, for example, beyond discursive symbols of suffering intended for human consumption, like the ubiquitous polar bear on a fragment of Arctic sea ice. Life, distinct from vitality attributed to all matter, is a salient category because living things have bodies, life courses, communities, and finally, death. Life as a substance of climate physically contains environmental change in bodies and populations. Along with people's

lived experiences of climate change, nonhuman life forms also live with, express, adapt to, and perish in response to altering, global environmental conditions.

4 | SCIENCE AND POLICY, EXPERIENCED AND EMBODIED

In this frame, I analyze science and policy as things containing and expressing the substance of climate. These domains, traditionally considered in a discursive sense, also contain material realities that make some actions possible while limiting others. The work of science has a clear material culture to it, as well, one that has changed over time with experiments and new technologies (Galison, 1997). These objects mediate the practice of science, shaping knowledge as well as making phenomena visible, invisible, or measurable. Policy is also enabled by the physical environment of documents, negotiations, and institutions. For example, the forms, brackets, and “figures seen twice” that Riles depicts in *Network Inside Out* (Riles, 2000), are material frames that shape the content of policy documents. The materiality of climate science and policy engages with the material conditions and processes of the natural world that these practices seek to understand and ameliorate; this section examines efforts to understand the materiality of climate science and policy with an emphasis on the substance of knowing and solving anthropogenic global warming.

Conceptual work on representation, mediation, visualization, and enactment among scientists and their practices continues to be a matter of concern among scholars of science and technology (Coopmans, Vertesi, Lynch, & Woolgar, 2014). For example, scientists employ various tactics to make the distant, theorized, or otherworldly material and embodied, such as Messeri's configuration of “resonance” in which “the knowing and sensing subject detects and amplifies connections between discrete, distant objects and worlds,” which also includes an “attribute of physical excitement, exemplified by...enthusiasm” (2017, p. 132). Authors of Intergovernmental Panel on Climate Change assessment reports consider the political implications of color in their report figures—for instance, as the “burning embers” images may be too alarmist in an environment of heavy scrutiny on climate scientists and their findings (Mahony & Hulme, 2012). Visualization philosophies and technologies change over time, most spectacularly demonstrated by the zoomed-out view from satellite observation, which recast environmental and territorial imaginaries (Yusoff, 2005).

Objects and phenomena require mediation and interpretation to be understood by scientists. As Helmreich (2015) notes, empirical phenomena like life, water, and sound are abstractions, but abstractions with matter present; therefore, “their status as abstractions is supported by a variety of *formalisms*—formal models, maps, simulations and equations that attempt to represent and manage their *material* qualities as well as the fleeting empirical or experiential coherence of these qualities” (p. xx). Mediation and interpretation, then, rely on more than managing to bring forth the abstract, but the abstract already made material, either those materials of “nature” or of scientific records of observable phenomena—the marks that nature makes.

Natural objects also have a history which various cultural groups read and interpret. For example, the shift of what glacial change signifies and is caused by—internal glacial dynamics and anthropogenic climate change—is mediated through observations made by locals, explorers, naturalists, and scientists as they live with and travel on and around glaciers (Orlove, Wiegandt, & Luckman, 2008).

Nature as data and material instantiations of knowledge are powerful tropes among scientists as well as STS scholars. Richard Alley, a prominent American glaciologist, writes how ice cores hold the history of the Earth's atmosphere, noting colorfully that “ice cores also show that the ice age came and went in a drunken stagger, punctuated by dozens of abrupt warmings and coolings (2000, p. 4). The ice cores are “libraries,” (p. 11), “archives” (p. 31), and “calendars” (p. 43) according to Alley, as he explains the methods and findings of ice coring in travel narrative form, interspersed with jokes from his field camps. In a similar vein but from a critical feminist science studies perspective, Melody Jue analyses how the material properties of seawater form and displaces notions of archives and databases (2014). Scientists alternately reveal the nature of these archives or piece them together through their research, making wild taxonomies legible to humanity (as Helmreich 2009 demonstrates). Climate modeling itself, with a long, complex history of simulating Earth system processes, forms a “digital earth” with all of the imaginative and material consequences of such a formation (Edwards, 2010; Yusoff, 2009).

Scientific interactions with nature are sometimes interpolated into the discourse of public works, especially of infrastructure, texts, or archives. Waves become texts in which experts can read the future of the Earth as it experiences climate change; these waves “to wave scientists, have an anthropology inside them, an account of humanity” (Helmreich, 2014, p. 269). Ice cores, in Yusoff's analysis, are archives of global human interaction with the atmosphere, and also require various infrastructural arrangements, from the field camp on the Greenland or Antarctic ice sheets, to the techno-coolers used for transport, to the frozen laboratories where they reside (2008). Public, corporate, and scientific imaginaries of infrastructures can conflict with their reality in nature, as Ballesterio (2016) explains: considering the aquifer under Guanacaste, Costa Rica as a water tank instead of a sponge—and considering an aquifer only in terms of water availability instead of a hydrogeologic system—revealed knowledge gaps and laid bare historical water conflict.

The material components of institutions, from infrastructure to legal regimes, interact with and effect human and nonhuman communities around them. Public interactions with the necessities of life are materialized through enactments of infrastructure, law, and citizenship, creating, as Anand explains in his ethnographic research on Mumbai's water system, a technopolitical assemblage at risk as natural and social pressures amplify (Anand, 2017). Foster (2017) articulates how nature, specifically the South African plant hoodia, reacts to scientific and patent work around it as well as how the materialities of law impact people and things unequally, or work to reproduce existing inequalities.

Pricing carbon rationalizes it for policy making and therefore commodifies it (Günel, 2016), but carbon is also a material-semiotic relation which physical and metaphysical meaning, particularly in the traces of human activity that carbon dioxide represents in the atmosphere. As Whittington (2016) notes, "human atmospheric activity is materialized in carbon emissions, which in turn provide the basis for working on what new forms the human might take" (p. 48). Increased carbon dioxide is a chemical trace of human activity, one that remains present beyond human lifetimes and into geological time.

Climate is not only substantive from the vantage of science and technology; climate policy also has a substance, a texture that enables and resists some forms of action. In his ethnography of the dynamism of bureaucracy, Matthew Hull centres his analysis on the materiality of the document, of paper, and the political possibilities implicitly or explicitly contained within. Hull contends that "the producers of government documents, much like scientists, claim to represent, engage with, or constitute realities "in the world" independent from the processes that produce documents" (2012, p. 5). Florian Weisser (2014), following Ferraris's notion of "documentality" (2012), contends that a climate policy document matters not only in the ideas contained within it but because the document "is the legitimization of the practice of negotiating itself" (p. 53). That governments, institutions, and bureaucracies produce and exist within a material universe challenges the conventional idea that policy exists only in the realm of negotiated discourse.

Moving between the substantive worlds of science to the substantive worlds of policy is tricky, however, as epistemological and political difference make the road bumpy. For example, in my Antarctic ethnography, the perceived separation of two sorts of expertise, scientific and diplomatic, reinforce challenges in crossing between the two to make decisions based on scientific evidence (O'Reilly, 2017). A core ingredient of this difficulty is the virtually incommensurate material worlds science and policy occupy, in Antarctica and elsewhere.

This incommensurability opens up spaces for policy negotiation. For example, a relatively new United Nations assessment, the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) has, with a top-down, international effort, repositioned local and indigenous ecological knowledge alongside the natural and physical sciences, moving indigenous knowledge from the text box case studies that such examples usually occupy in international reports to the substantive document itself (Díaz et al., 2015). Considering non-Western forms of knowledge in international scientific assessments reflects more than a nod to underrepresented knowledge practices (Ford et al., 2016). The material practice of including indigenous knowledge into the architecture of the report affords opportunities, however slight and partial, to communicate material understandings of places, worldviews, and people that are typically erased from the standardizing processes of assessment. These vantages lend power and legitimacy to climate negotiations, particular when matters of equity and justice are up for discussion.

Materialism as a theoretical vantage and methodological commitment can inspire particular political formations as well. Bennett argues that "a vital materialist theory of democracy seeks to transform the divide between speaking subjects and mute objects into a set of differential tendencies and variable capacities" (2009, p. 108). In contrast, Latour suggests that stitching society and nature back together into a "Parliament of Things" in which "the mediators have the whole space to themselves" as subjects and objects, in this view, consist entirely of mediated reality (1993, p. 144). Bringing materiality into climate politics can help dislodge the notion of a boundary between science and policy; instead of disparate discourses and sets of expertise, the substance of climate can thread its way through these multiple domains.

The material objects and technics of climate science and policy render and organize knowledge in particular ways. The work and outputs of scientists and policy makers—articles, policies, laboratories, field sites, diplomatic meeting venues—are not only the domain of conceptual abstractions, but also physical things and places in which the material reality matters. The substance of climate is not simply contained or represented by experts, but is constrained and enabled by the systems, methods, and institutions they arrange.

5 | CONCLUSION

"The atmosphere is as intimate and personal as a breath of air in our lungs," writes Fleming, Janković, and Coen (2006), adding that "it is also a global phenomenon with international political and economic dimensions" (p. ix). That material relationships break between affective, personal scales and those of international reach suggests that somewhere along the chain, the substance of climate becomes either to matter less or else unimaginable. This review has sought to rectify this situation.

This review has considered the substance of climate through environmental elements, life, and material approaches to climate science and policy. The three frames are connected by an attention by scholars in the social sciences and humanities to environmental degradation in various forms, from the loss of biodiversity to the haunting aura of decimated landscapes (Tsing, Bubandt, Gan, & Swanson, 2017). The substance of climate is the intersection between the almost unimaginable and the intimate and embodied. Sometimes it is the methodological and ethical scale that matters here, or the shifting of perception and cognition of the phenomena happening around and to us. This intersection is mediated through conceptual and disciplinary approaches as well as the work of science and policy—or knowledge and governance more broadly.

Narratives matter. Climate communicators know this, providing robust advice to scientists, educators, and politicians on how to frame climate change to make sense for their audience. Narratives, however necessary, distil climate change into discourse, as if it is a concept only and not grounded in the material world around us. And even though this article is rooted in the concern that the global scale of climate change often obstructs experiential, tactile, and local registers, this global scale also matters. Without pulling back to view the planetary scale—a feat of imagination and technology—global climate change could not be apprehended. In the third frame on science and policy, above, I explained how the construction of the global scale—climate science—and the construction of global solutions—climate policy—also contains material realities that shape the knowledge and actions available to us.

Therefore, I extend this argument to contend that the substance of climate matters. Sensorial engagements with the changing climate, through scientific research, diplomatic processes, or everyday life, create knowledge from the expert to the quotidian. Humans are interactive with their environments, like every other being and thing described in this article. However, ascribing agency to nonhumans is not the same as ascribing responsibility. People pollute—some much more than others—and bear it in their bodies along with every other earthly being and thing. People pollute and melt glaciers with it and bear the transformation of polar landscapes elsewhere, reforming our coastlines and homes and habitats. Or more accurately, some of us make most of the pollution while requiring other people to bear the transformations elsewhere. Considering the material realities of climate change re-situates the problem as well as potential solutions.

Analyzing the substance of climate upends the dominant, though unrealistic, idea that strong science feeds neatly into policy decision making. Instead, the substance of climate allows us to consider the scientific and environmental impacts of climate change immediately alongside the power dynamics that enable and can solve this problem.

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CONFLICT OF INTEREST

The author has declared no conflicts of interest for this article.

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