Turbulence as an immersive aesthetic for climate extremes

Nagida Helsby-Clark
UNSW iCinema Research Centre & CSIRO's Data61
Sydney, Australia
n.helsbyclark@student.unsw.edu.au

Abstract

This paper explores how humans may grapple with the shifting interrelationships within climate-fuelled extreme wildfire behaviour and ocean dynamics, and our own role both feeding and being impacted by these permutations. I briefly investigate existing approaches to climate aesthetics and representations of turbulence, anchoring these to my practice across two immersive visualisation projects; *Ocean Explorer* and *iFire*. I argue that traditionally static renderings miss crucial opportunities to support more embodied understandings which leverage more visceral ways of knowing. I reflect on the nature of the ecosystems under examination as complex networks of interrelationships. In doing so, I challenge traditional distinctions between human and nonhuman, machinist and "natural" elements. Ultimately, I prioritise a relational ontology which acknowledges the vitality of these disparate agencies, while recognising asymmetry in power dynamics and the potential for emergent social and terrestrial structures. By displacing the human's role as subject atop a hierarchy of relations, I underscore the need for a more than human, immersive approach to the aesthetics of turbulent climate extremes.

Keywords

Climate aesthetics; immersive visualization; virtual environments; turbulence; augmented reality; embodied sensemaking; human and nonhuman agents; artificial intelligence; oceanography; wildfires.

Introduction

Climatic shifts increasingly manifest in turbulent local phenomena, provoking cyclones, stirring ocean eddies and fuelling violent pyroconvective events. As human activities distort and mutate the very atmospheres surrounding us, comprehending these extremes beckons an evolution in traditional aesthetic paradigms. An immersive aesthetic must recognise our embeddedness within these complex systems, enabling multisensory and multi-agent exploration.

While fires and oceans appear elementally opposed, they share a common grounding in fluid dynamics. Fluid dynamics is a subset of fluid mechanics, a branch of physics which investigates the motion, behaviour and properties of fluids. In a physical sense, turbulence represents a style or regime of flow, characterised by chaotic and highly irregular fluctuations in velocity and pressure. Michel Serres expands on the notion of turbulence, applying the characteristics of these unpredictable and chaotic patterns to knowledge, language, and societal structures. [1] The shifting flows and turbulences characteristic of some ocean currents and extreme wildfires are the dominant site of enquiry for my practice. I echo Serres' approach, transforming the notion of turbulence in a to emphasise the evolving relations between human and nonhuman actors. Turbulence here connotes the blending of the scientific, artistic and cultural dimensions of these flows.

Materialising turbulence

The work of contemporary artist Rafael Lozano-Hemmer exemplifies a form of materialisation of human and climatic relations. Lozano-Hemmer's 2023 exhibition, *Atmospheric Memory* imagines Charles Babbage's (1837) statement that, "the atmosphere is a vast library that contains all the words that have been spoken in the past". [2] The exhibition comprises several immersive works which disrupt distinctions between the physical, digital and atmospheric. *Volute 1: Au Clair de la Lune* is the world's first 3D-printed speech bubble [2]. The momentary aspiration of the phrase "Au claire de la lune" passes through scanning technology and is later printed, immortalising this fleeting phenomena into a tangible rendering. This turbulent air movement is preserved in a visible and tactile form. Lozano-Hemmer's work draws inspiration from the Ancient Mesoamerican visual tradition of the volute; a scroll-like version of a speech bubble, representative of song, words or breath. Lozano-Hemmer describes the remarkable accuracy of these ancient scrolls when compared to Navier-Stokes equations–some of one of the fundamental laws of fluid mechanics. [3] This example illuminates the permeable nature of the barriers between science, art and intuition in the pursuit of a climate aesthetic.

Fires in flux

Wildfire researchers are increasingly exploring wildfires through the lens of fluid dynamics, noting turbulence as a characteristic of extreme wildfires under climate change. Vorticity-driven lateral spread is one turbulent phenomenon of these fires. [4] Typically, the lee side of the slope would be a safe place. In extreme wildfires, the wind recirculates with cyclonic force, sending the fire down the once protective side of the hill. Turbulence is also a driving force behind wildfires coupling with the atmosphere, generating their own weather conditions such as pyrocumulus clouds and fire cyclones. [5]

iFire (Figure 1) is a cross-modal immersive experience, designed to support researchers, creatives and firefighters to visualise and rehearse encounters with extreme wildfires. *iFire* is situated in projected, cinematic environments including a 360 degree, 3D cinema, a 130 degree cinema, laptops and tablets. The experience is powered by Unreal Engine, a real-time game engine commonly used in virtual production. Participants are immersed within a wildfire scenario, either modelled on a real-world fire or within novel scenarios generated by AI. They can explore fire behaviour and test 'what if' scenarios by manipulating parameters such as wind speed and temperature. The experience provokes an embodied engagement with a fire scenario, in which cognitive deliberation and visceral intuition are leveraged to support participants to make sense of these turbulent processes and their own role within them.

My role in this collaborative project is designing an immersive soundscape to evoke an auditory experience of turbulence. As part of the design process, I conducted interviews with wildfire researchers. The following are extracts from these accounts, evidencing the perceptual qualities of the experience of seeing these fires firsthand and how this impacts their ability to understand wildfire behaviour in a scientific context,

> *"Two things really stop you in your tracks. One is just how hot it is next to a fire. The first time you feel it it's just like, this can't be right. You're just waiting for yourself to burst into flames half the time. And the other thing is noise. It changes you. Suddenly it's like, oh shit, this wasn't in the books. The noise that you hear is turbulence. People say it's like a jet engine…So having an understanding of how powerful these things are, I think I have an advantage experiencing that, because as a researcher sometimes you can just tell when something's not right."*

Another participant remarked,

> *"It's like a freight train or a steam engine. It can get really, really loud, that roar of the flame and the noise of the wind through the remaining vegetation. And all the subsonic bits I think that are in there that you feel but don't hear just add to the ferocity of the experience. And then you add to that the fact that most wildfires in Southeastern Australia, at least, most of them are going to be blocking out the sun. So it's going to be dark as. so it's now night time in the middle of the afternoon and you've got this horrendous noise heading to you. You've got no clue what it is or where it is except it's very uncomfortable and you want to get out and you don't know which way to go... If you are aware of what something looks like in reality, you can see whether it looks like reality in a simulation. You can't tell if it is real, but you can tell when it's not real."*

Figure 1. *iFire in iCinema's 360-degree cinema*. Note. Representation of *iFire* in iCinema's 360 degree cinema. From Del Favero, D. et al. (2022). *iFire* [3D model]. Image by S. Cotterell. ©iCinema Centre, reproduced with permission.

The Beaufort scale is a model of wind velocity. While the scale abstracts fluid dynamics to symbols, the descriptions of these symbols correspond to visceral experiences in a physical scenario, such as branches swaying or dust stirring. *iFire* enables embedded encounters with actual and probable fire scenarios, to re-imagine this sort of aesthetic engagement in a safe environment, providing numerous multisensory narrative pathways.

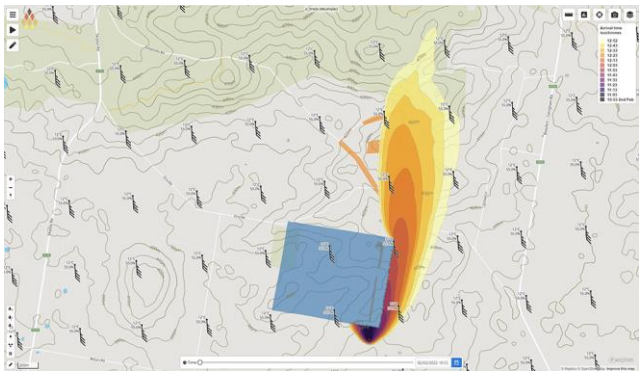

Figure 2. *Wind in CSIRO's Spark wildfire simulator*. Note. Wildfire visualisation in CSIRO Data 61's *Spark* simulator. Author's own (2023).

"Monster" eddies and marine heatwaves

Through *Ocean Explorer*, I investigate possibilities for augmenting humans in virtual environments to better comprehend turbulent ocean dynamics such as eddies. [6] In scientific visualisation, these dynamics are typically rendered in the form of flow fields, with arrows representing the velocity—the speed and direction—of the current. [7] They may

also be inferred from isosurfaces displaying temperature. While more sophisticated versions may feature animated arrows or colours, they are largely restricted to two-dimensional, visual accompaniments. Ocean currents may alternatively be understood through humans' experiences being immersed in physical oceans, where the sensations engendered by flowing water provide a tacit understanding of directionality and force, even while our eyes may be closed. Yet, this capacity for embodied oceanographic understanding is lost in simulations, distanced from direct human grasp due to their scale or impenetrable depths. Indeed, a recent "monster" eddy observed off the East coast of Australia was 400km wide and 3km deep, spinning at 8km/h. [8] [9] The heat captured by this eddy has the potential to generate a marine heatwave. In *Ocean Explorer* I expand the scientific paradigms for flow visualisation, pairing a real-time ocean visualisation with haptic feedback so that participants may feel the flows as vibrotactile encounters on their hands. My role in this collaborative project is to augment the visual experience with these experimental approaches. These tactile renderings are powered by simulated data, reflecting real-world ocean observations. Yet, they are not intended as photorealistic replicas, but abstracted to evoke a perceptual response. These sensations are experienced within a virtual reality head-mounted display, enabling users to navigate ocean currents at depth through time (see Figures 3 and 4).

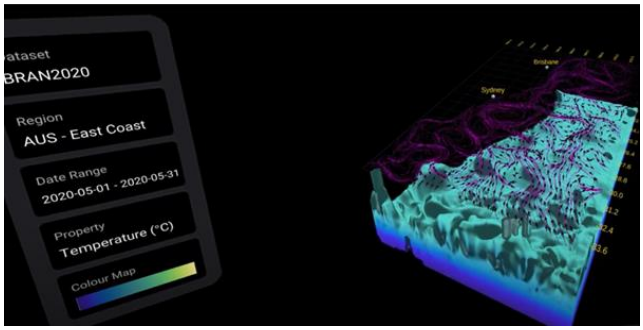

Figure 3. *Ocean Explorer flow representations in virtual reality*. Note. Still from video capture of *Ocean Explorer* experience, through Oculus Quest Pro virtual reality head-mounted display. Image depicts isosurfaces and flow fields, representing ocean currents, including eddies, along the East coast of Australia, using Bluelink BRAN Reanalysis Model, May 2020. From P. Grimmett (2022) *Ocean Explorer* [still from video].

In designing for dynamic engagement with ocean currents, I am not seeking to replace scientific sensemaking forms, but to augment them with more visceral ways of apprehending these phenomena.

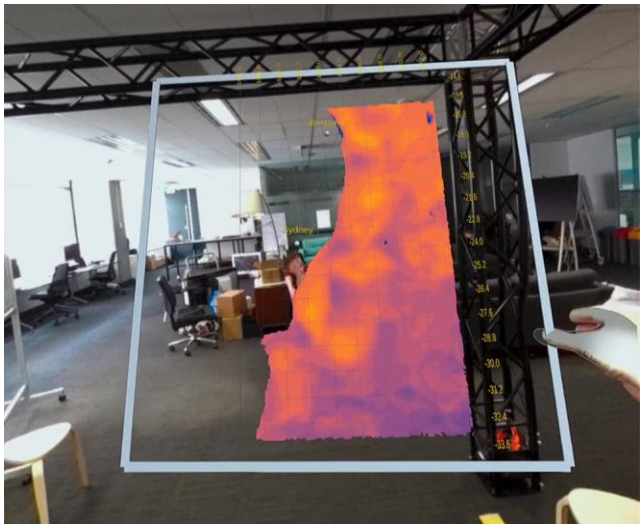

Figure 4. *Ocean Explorer flow representations in augmented reality*. Note. Still from video capture of *Ocean Explorer* experience with passthrough, enabling an augmented reality perspective. From P. Grimmett (2023) *Ocean Explorer* [still from video].

While climate aesthetics has traditionally seen divisions between scientific and artistic paradigms, Badia et al. underscore the potential for a climate realism that reconciles these approaches in the aesthetics of weather, atmosphere and climate. [10] For Badia et al., realist approaches typically fail to adequately capture the complex entanglements between humans, social structures and climate phenomena. However, the authors' notion of climate aesthetics bridges humanities-based ideas of climate with scientific knowledge. Badia et al. contend, "the core suggestion of *Climate Realism*, then, is that weird weather today is not weird just because it is unseasonable…it erodes traditional distinctions that have stabilized disciplinary work in both the arts and sciences." [10] This reckoning with the complexity of climate causes and impacts necessitates a revision of aesthetic concepts and practices. This includes acknowledgement that our very understanding of climate change is contingent on the synthetically manufactured instruments used to measure it. Badia et al. describe, "the way the Anthropocene calls forth the project of realism requires perspectives that include human, nonhuman, elemental and even computational semiotes". [10] Ultimately, any climate sensemaking activity must acknowledge the complex interrelationships and interactions between human and nonhuman actors including sensing and computational machines (a concept I return to later in this paper). For Badia et al., emergent material approaches in the arts may, "recompose[e] the concept, atmosphere, and mood of climate". [10] My practice sits in this intersection, ultimately espousing a more than human and material paradigm for climate aesthetics. Through *iFire* and *Ocean Explorer*, I translate these ideas into my practice by exploring techniques for rendering tangible wind,

atmospheres and fluid dynamics as manifestations of climate processes within immersive experiences.

Hyperobjects, geohistory and future climate imaginaries

Timothy Morton's concept of hyperobjects provides a frame to conceive of wildfires, particular ocean dynamics and the associated challenges of perceptual representation they entail as manifestations of climate change. Hyperobjects are, “things that are massively distributed in time and space relative to humans” [11]. For Morton, global warming is a hyperobject, imperceptible to humans directly or in its entirety, though we may frequently observe its local manifestations. Other examples Morton cites include black holes, the Florida Everglades and Lago Agrio oil field in Ecuador. Morton grounds their analysis in an object-oriented ontology (OOO) approach; a 'Russian doll' conception, where “all the relations between the objects and within them also count as objects”. [11] Under Morton's conception, individual instances of wildfires, ocean currents, weather or indeed humans would operate as objects nested within other objects, which may ultimately discover themselves within hyperobjects, such as "Earth, the biosphere, climate, global warming". [11] Two additional and significant properties of hyperobjects are that "any “local manifestation” of a hyperobject is not directly the hyperobject" [11], and that they are "real" in the sense that they exist beyond mental conception, although parts of their reality at various times may be undiscoverable to human perceptual cognition. While we may contemplate instantiations or elements of hyperobjects, their entirety is withdrawn from us. While I later critique Morton's approach, it does raise important considerations for how humans may conceive of their relationship to phenomena on spatial and temporal continuums expanding from local to planetary, and exceeding single human lifespans. This ontological framework bears significant ramifications when contemplating aesthetic dimensions of [hyper]objects such as climate change, and their local manifestations in wildfire and ocean dynamics.

Morton's approach raises the challenges of representing phenomena beyond the direct grasp of human perception. In the example of plutonium, Morton contends, “The future of plutonium exerts a causal influence on the present, casting its shadow backward through time”. [11] In global warming, weather events become instances of global warming, "flimsy" representations of a larger hyperobject which is largely invisible, "You can’t see or smell climate. Given our brains’ processing power, we can’t even really think about it all that concretely”. [11] Our very notion of world depends on aesthetic effects, and in the case of global warming, this representation is largely mediated through technologies such as sensing equipment or digital visual representations. These challenges are reflected in my practice within the *Ocean Explorer* project, translating ocean data into visceral encounters. Ocean eddies are a phenomena that may not be directly observable. They may be represented on a surface level from satellite imagery, or simulated using digital software, however humans cannot directly observe large-scale eddy movements in their entirety. Deep ocean undercurrents present further challenges due to the limits of human ability to traverse the ocean floor, and the availability of sensing equipment and data. In the context of wildfires, subtle shifts in wind may drastically alter wildfire trajectories. Additionally, these phenomena are being dramatically altered by global warming, to the extent that they may defy expectations defined by past observations, rendering them increasingly elusive to the human perceptual grasps and the limits of human memory. My practice explores the role of more embodied representations to counter the increasing material abstraction of these crises. rendering turbulent processes more directly "palpable".

Badia et al. confront the challenge of envisaging climate futures in the context of deep uncertainties. They query, “What pressure does this non-reproducibility put on aesthetic modes of representation that seek to see futures never realized”. [10] Indeed, prominent climate scientists warn climate impacts are accelerating faster than imagined. [12] Diran and Traisnel argue that mimetic approaches to climate aesthetics realise their limits when imagining unknowable futures. [13] For this purpose, Badia et al. call for “emergent techniques in the visual and literary arts”; a coalescence of scientific, humanities and artistic practices to conceive the aesthetics of climate futures. [10] *iFire* represents one attempt at demystifying plausible futures under different climate extremes. *iFire's* AI system enables users to dynamically generate infinite wildfire scenarios in a real-time environment. This capacity for participants to contemplate novel, evidence-based scenarios re-imagines existing approaches which typically recreate past fires. The use of AI also enables participants to leverage physical fire models able to capture complex, turbulent processes such as fire-atmospheric coupling.

To comprehend such a ‘thing’ as global warming, one must traverse scales of space and time, from micro, local instances of eddies and fires, to macro scale views of current movements across oceans. We must look across time, from millisecond shifts in wind patterns which spark a flame and alter its trajectory, to a deep-time view of pre-human and pre-industrial records of Earth's climate, to the possible future implications of the technologies we are using. In the face of this sensemaking task, our current aesthetic paradigms reveal themselves to be lacking.

Manuel De Landa echoes these notions in *A Thousand Years of Nonlinear History*. [14] Here, De Landa offers a deeper history of matter, charting the course of emergent processes through geology, biology, human language and social systems. In establishing his account of history in time, De Landa arguably diverts from some of Morton's incidental anthropocentrism, grounding the narrative in a non-hierarchical grouping which emphasises the import of all forms of matter in potentially self-organising systems. Yet De

Landa's history is still restricted to the last 1000 years. Kathryn Yusoff conceives of materiality in the context of deep time and geologic histories, imagining both into the deep past and distant future; displacing human scales of reference while acknowledging the political history of matter in the contexts of colonisation and capitalism. [15] For Yusoff, this “end of the world” moment presents an opportunity for a reconfiguration, both of our understanding of the past and how we carve out a future less reliant on extractive processes. [15]

If, as Morton contends, the project of aesthetics is to reckon with humans' place in the world, how do we account for the imbalance impact of "human" extractive processes in our current ecological crisis? The underlying issue of power relations and distributed culpability between human and nonhuman actors appears inadvertently sidelined in OOO and related ontologies. My practice seeks to hold space for dismantling human exceptionalism, while acknowledging uneven culpability for humans in catalysing climate change.

"The End of the World"

Morton embraces a flat ontology of objects within objects in expansive, nested yet never networked, stacks of humans, nonhumans, technologies, and other entities. [11] For Morton, ecology is this intimacy, a callback to the origins of the term as *oikos* or *home.* It is in this recognition of hyperobjects such as global warming as part of our ongoing social relations that provides hope for a future which addresses these crises and offers possibility of coexistence. For Morton, “By embracing hyperobjects that loom into our social space, and dropping Nature, *world*, and so on, we have a chance to create more democratic modes of coexistence between humans and nonhumans” [11]. For Morton, this is necessarily an aesthetic ambition, as aesthetics performs a critical role in facilitating how humans perceive 'nature' and experience their place in the 'world', or these shifting ecologies of which we are a part [16]. Yet, Morton’s conception of hyperobjects may be seen as anthropocentric even as they critique these traditional human-centred distinctions between ‘nature’, ‘world’, and humans. By conceiving of hyperobjects in temporal and spatial relation to humans, they reinforce this worldview.

Yusoff highlights disparities in the extent all "humans" are implicated in resource extraction and ecosystem exploitation, criticising the universalising depiction of culpability for global warming and environmental decay. [17] Indeed, Yusoff writes, "As the Anthropocene proclaims the language of species life–*anthropos*–through a universalist geologic commons, it neatly erases histories of racism that were incubated through the regulatory structure of georelations" [17]. Diran and Traisnal further critique the history of invoking environmental crises as a means of erasing historical power imbalances. [17] For Diran and Traisnal, global warming must be acknowledged as, "the consequence of a deeply asymmetrical and theoretically mystified exploitation of planetary resources", which cannot be divorced from their material power relations. [13] In describing more than human approaches to immersion, I avoid the term 'posthuman', as acknowledgement of the ways in which humans have historically been excluded from design considerations.

"Nature" as a series of interactions

Similarly, Latour conceives of environmental, human and social actants within a relational ontology, holding "nature" and "culture" as indivisible forces. [18] Latour elevates the Earth's status from object to actant; far from being a passive, inert backdrop for human subjects, Latour's Earth is dynamic, *metamorphic*–a force. He concedes scientists had to invent terms such as "Anthropocene" and "tipping points", "in their attempt to understand this Earth that seems to react to our actions” [18]. Within Latour's flat ontology, nonhuman forces and their interactions hold as much potency as any human-human or human-nonhuman transactions. Latour narrates the sweeping contest between the Atchafalaya and Mississippi rivers, and the Engineer Corps' futile attempts to quell these indefatigable forces, as described in John McPhee's novel *The Control of Nature.* The Atchafalaya's attempts to catch the Mississippi are held to be as pertinent a display of agency as any situation of human war. Latour's characterisation of "nature" as a lively series of exchanges of forces has significant implications for both *iFire and Ocean Explorer,* as sensemaking experiences that evoke ecological phenomena. Indeed, extreme wildfire events demonstrate turbulent coupling between fire and atmosphere, which fuel each other in self-perpetuating, autopoietic cycles. As in the contest of rivers, humans may be largely powerless to stem these forces at the height of their powers. However, humans play multiple roles in the genesis and management of these scenarios. In the face of such complexity of agential exchanges, human-centred interaction frameworks reveal themselves to be profoundly inadequate.

Latour [18] hints at a dissolution of traditional artistic and Kantian subject-object divides, “From now on, there are no more spectators, because there is no shore that has not been mobilized in the drama of geohistory. Because there are no more tourists, the feeling of the sublime has disappeared along with the safety of the onlookers”. Rather than presenting a passive depiction of environmental phenomena, the implications of these philosophies would be to generate experiences which encapsulate or represent sensitivity, reactivity and dialogic forms of conversation between human and nonhuman matter or agents. This includes the potential for dynamic interactions and reactions between the environmental phenomena themselves. *iFire* is an example of this distributed interactive framework at play. [19] While human users may participate in the experience, the use of AI to envisage novel fire scenarios contains an emergent potential. Wildfires may couple with atmospheric variables, driven by

an AI system, informed by models based on empirical field observations and physic-based processes. This echoes DeLanda's characterisation of the "self-organising" and emergent properties of *matter-energy*, a bottom-up approach to conceiving of how ecosystems and social systems emerge from these dynamic interactions. [14] However, Latour de-emphasises the role of these broader systems in favour of individual agencies. Under this conception, fluid dynamics of wildfire, oceanic and atmospheric processes become part of the distributive agency of both human and nonhuman forces. This conception expands interaction paradigms for both *iFire* and *Ocean Explorer*. An immersive notion of flux thus entails the complex dynamics, not only of the physical processes of these phenomena, but of the human and nonhuman actors, including co-active sensing equipment, immersive apparatus, human and AI agents.

Latour's (2017) notion of the indivisibility of nature/culture, in favour of a critical or Earthbound zone which we all inhabit, prioritises an atomised ontology which apparently rejects the possibility of a higher relational configuration. The figure of *Gaia* replaces the now defunct notion of "nature", emblematic of the layer of interactions taking place within a critical or metamorphic zone. In this zone there are no barriers between agents; Latour instead conceives of permeable linkages within flowing "waves" of interaction, in which one actor's intentions or compulsions bend or disrupt those actors in their vicinity. Latour draws upon Lovelock's (1972) depiction, in which the various agents manipulating their neighbours manifests as borderless, overlapping ripples or "waves of action" (Latour, 2017, p. 75). This call to view interaction through the lens of fluid exchanges of energy and matter evokes strong parallels with my practice in representation of fluid dynamics. For Latour, this is far from a metaphorical exploration; Latour conceives of this metamorphic, *Gaian*, ontology as representative of the real organisation of atomic matter. Under this conception, fluid dynamics of wildfire, oceanic and atmospheric processes become part of the distributive agency of both human and nonhuman forces. This conception expands interaction design parameters for both *iFire* and *Ocean Explorer*. A notion of flux here entails the complex dynamics, not only of the physical processes of these phenomena, but of the human and nonhuman actors, including intermediary sensing equipment, immersive apparatus, human users and AI agents.

While Latour (2017) calls upon Lovelock's figure of *Gaia*, he rejects the idea of a supreme being or overarching system. For Latour, *Gaia* is not a superorganism, but the metamorphic accumulation of these agencies; the non-theistic "'blur" or "muddle" resulting from these intersecting waves of forces. Indeed, Latour (2017, p. 80) declares *Gaia* "the anti-system". In this model, while agents fluctuate in scale, from micro to macro, there is no greater purpose. Each atomic and subatomic level of agent is driven by an end unto itself. While Latour's conception provides a stronger resolution than OOO approaches by better recognising the relational and active/reactive capacities of agents, his rejection of systems has problematic implications for notions of collective knowledge and social structures. Latour's boundless layers of forces seemingly allow no fixed walls to which conceptions of asymmetrical power and capital may affix themselves.

Turbulence in immersive design

Through *iFire* and *Ocean Explorer*, my practice explores turbulence in immersive environments as tangible instantiations and local manifestations of climate change. While fluid dynamics are not necessarily related to climate, they are increasingly implicated in and representative of more extreme variations in wildfire and ocean dynamics fuelled by global warming. My practice explores how an aesthetic notion of turbulence may support more embodied forms of sensemaking for climate change. Turbulence here is an immersive design lens drawing on relational ontologies. It is a provocation that departs from Anthropocentrism, recognising the vital exchanges between human and nonhuman, biological and technological actors. Turbulence prioritises designing for tangible and embodied understandings of fluid dynamics in "natural" phenomena such as oceans, wildfires and atmospheres. While these more than human exchanges are taken as non-hierarchical, my analysis recognises the potentials for collective structures and social systems as emergent properties of these interactions. It holds space for historical material and political analyses that identify disruptions to global climate as manifestations of extractive processes and power asymmetries. Ultimately, turbulence is an aspirational grouping; a collection of various strands throughout philosophy, art and science, as a contribution to an ongoing reckoning in with the limitations of human-centred paradigms in the face of the Anthropocene and beyond. Turbulence is inspired by the potential for more immersive, tangible dialogues between human and nonhuman actors to leverage visceral understandings of the fluid processes in which we are all, ultimately, protagonists.

Acknowledgements

This research is being supported by the Australian Government through the Australian Research Council's Laureate funding scheme (FL200100004) and through Commonwealth Scientific and Industrial Research Organisation's (CSIRO) Data61.

Author Biography

Nagida Helsby-Clark is a design researcher and PhD Candidate at UNSW's School of Art & Design, supported by a scholarship from CSIRO's Data61 – the data and digital specialist arm of Australia's national science agency. Her research focuses on immersive aesthetics and embodied sense-making for climate extremes. She conducts experimental research across Data61 and UNSW's iCinema Research Centre, in particular on the ARC-

funded *iFire* Laureate project. Nagida holds a Master in Visualisation, Simulation and Immersive Design from UNSW (2021), and has a background as a community organiser and climate-justice advocate.

References

[1] Serres, M. (1995). *Genesis* (G. James & J. Nielson, Trans.). University of Michigan Press.

[2] Lozano-Hemmer, R. (2016). *Volute*. Retrieved 05 October 2023, from https://www.lozano-hemmer.com/volute.php

[3] Lozano-Hemmer, R. (2023). Atmospheric Memory [Exhibition]. Exhibited at Powerhouse Museum Sydney August 12–November 5 2023. https://powerhouse.com.au/program/atmospheric-memory

[4] Speer, K., & Goodrick, S. (Eds.). (2022). Wildland Fire Dynamics. In *Wildland Fire Dynamics: Fire Effects and Behavior from a Fluid Dynamics Perspective* (pp. i–ii). Cambridge University Press. https://www.cambridge.org/core/books/wildland-fire-dynamics/wildland-fire-dynamics/0D2C6588135BBFBA01DDE61EA3AC8C5E

[5] Sharples, J. J., Hilton, J. E., Badlan, R. L., Thomas, C. M., & McRae, R. H. D. (2022). Fire Line Geometry and Pyroconvective Dynamics. In K. Speer & S. Goodrick (Eds.), *Wildland Fire Dynamics: Fire Effects and Behavior from a Fluid Dynamics Perspective* (pp. 77–128). Cambridge University Press. https://doi.org/10.1017/9781108683241.004

[6] Branchaud, D., Grimmett, P., Helsby-Clark, N., Krantz, E., & Weiley, V. (2023). Dynamic Ocean Explorer: Interactive XR Visualisation of Massive Volumetric Data for Ocean Science. *Proceedings of the SIGGRAPH Asia 2022 Real-Time Live!*, 1. https://doi.org/10.1145/3550453.3586014

[7] Fonnet, A., & Prié, Y. (2021). Survey of Immersive Analytics. *IEEE Transactions on Visualization and Computer Graphics*, *27*(3), 2101–2122. https://doi.org/10.1109/TVCG.2019.2929033

[8] Li, J., Roughan, M., & Hemming, M. (2023). Interactions between cold cyclonic eddies and a western boundary current modulate marine heatwaves. *Communications Earth & Environment*, *4*(1), Article 1. https://doi.org/10.1038/s43247-023-01041-8

[9] Roughan, M., Schaeffer, A., Li, J., & Keating, S. (2023, November 1). *A monster eddy current is spinning into existence off the coast of Sydney. Will it bring a new marine heatwave?* The Conversation. http://theconversation.com/a-monster-eddy-current-is-spinning-into-existence-off-the-coast-of-sydney-will-it-bring-a-new-marine-heatwave-216625

[10] Badia, L., Cetinić, M., & Diamanti, J. (2020). Introduction. In L. Badia, M. Cetinić, & J. Diamanti (Eds.), *Climate Realism: The Aesthetics of Weather and Atmosphere in the Anthropocene* (1st ed., pp. 1–16). Routledge.

[11] Morton, T. (2013). *Hyperobjects: Philosophy and Ecology after the End of the World*. University of Minnesota Press. https://www.jstor.org/stable/10.5749/j.ctt4cggm7

[12] Hansen, J. E., Sato, M., Simons, L., Nazarenko, L. S., Sangha, I., Kharecha, P., Zachos, J. C., von Schuckmann, K., Loeb, N. G., Osman, M. B., Jin, Q., Tselioudis, G., Jeong, E., Lacis, A., Ruedy, R., Russell, G., Cao, J., & Li, J. (2023). Global warming in the pipeline. *Oxford Open Climate Change*, *3*(1), kgad008. https://doi.org/10.1093/oxfclm/kgad008

[13] Diran, I., & Traisnel, A. (2020). The poetics of geopower: Climate change and the politics of representation. In L. Badia, M. Cetinić, & J. Diamanti (Eds.), *Climate Realism: The Aesthetics of Weather and Atmosphere in the Anthropocene* (1st ed., pp. 124–137). Routledge.

[14] De Landa, M. (1997). *A Thousand Years of Nonlinear History*. Zone Books.

[15] Yusoff, K. (2020). Geologic realism: On the beach of geologic time. In L. Badia, M. Cetinić, & J. Diamanti (Eds.), *Climate Realism: The Aesthetics of Weather and Atmosphere in the Anthropocene* (1st ed., pp. 98–120). Routledge.

[16] Morton, T. (2009). *Ecology without Nature: Rethinking Environmental Aesthetics*. Harvard University Press.

[17] Yusoff, K. (2019). *A Billion Black Anthropocenes or None*. University of Minnesota Press.

[18] Latour, B. (2017). *Facing Gaia: Eight Lectures on the New Climatic Regime* (C. Porter, Trans.). Polity Press.

[19] Del Favero, D., Thurow, S., Stevens, G., Sharples, J., & Davidson, J. (2022). Visualizing the Unpredictable Behavior of Wildfire Using an Artificially Intelligent Aesthetic. In P. Alsina, I. Vilà, S. Tesconi, J. Soler-Adillon, & E. Mor (Eds.), *Proceedings of the 27th International Symposium on Electronic Art*. http://dx.doi.org/10.7238/ISEA2022.Proceedings

Bibliography

De Landa, M. (2006). *A New Philosophy of Society: Assemblage Theory and Social Complexity* (1st ed.). Bloomsbury.

Deleuze, G., & Guattari, F. (1987). *A Thousand Plateaus: Capitalism and Schizophrenia* (B. Massumi, Trans.). University of Minnesota Press.

Forlano, L. (2017). Posthumanism and Design. *She Ji: The Journal of Design, Economics, and Innovation*, *3*(1), 16–29. https://doi.org/10.1016/j.sheji.2017.08.001

Houston, S., & Taube, K. (2000). An Archaeology of the Senses: Perception and Cultural Expression in Ancient Mesoamerica. *Cambridge Archaeological Journal*, *10*(2), 261–294. https://doi.org/10.1017/S095977430000010X

James, P., & Haylock, B. (2021). Art in the Anthropocene: Apprehending abstracted crises, thickly. In B. Haylock & M. Patty (Eds.), *Art Writing in Crisis* (pp. 31–53). Sternberg Press. https://www.sternberg-press.com/product/art-writing-in-crisis/

Latour, B. (1987). *Science in Action: How to Follow Scientists and Engineers through Society*. Harvard University Press.

Latour, B. (1996). On actor-network theory: A few clarifications. *Soziale Welt*, *47*(4), 369–381.

Latour, B. (2007). *Reassembling the Social: An Introduction to Actor-Network-Theory*. Oxford University Press.

Morton, T. (2016). *Dark Ecology: For a Logic of Future Coexistence*. Columbia University Press.

Schleusener, S. (2021). A Politics of Things? Deleuze and the New Materialism. *Deleuze and Guattari Studies*, *15*(4), 523–542. https://doi.org/10.3366/dlgs.2021.0456

Whyte, K. P. (2020). Indigenous realism and climate change. In L. Badia, M. Cetinić, & J. Diamanti (Eds.), *Climate Realism: The Aesthetics of Weather and Atmosphere in the Anthropocene* (1st ed., pp. 69–81). Routledge.