



COLLOQUIA

Waves

An anthropology of scientific things

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I am honored to deliver the 2014 Lewis Henry Morgan Lecture, and I wish to begin by invoking one of Morgan's earliest writings, an 1841 essay on geology [SLIDE 2],* in which can be discerned stirrings of what would become Morgan's life-long interest in how organic agents—whether human or nonhuman (recall his book on the American beaver)—work with territory as a kind of living ancestral material (see Feeley-Harnik 1999). Morgan inaugurated this interest, intriguingly, in the sea, offering a meditation on the biogeology of coral reefs. Morgan wondered at how the coral “animalcules” of which reefs were constituted kept their skeletal armatures ever elevated above the water, a matter that is today of live ecological concern, as reefs disappear beneath rising seawater and waves [SLIDE 3]. Waves, slippery sorts

* To access slides referenced throughout this work, please download the file from the supplementary files section in the table of contents, or directly from here: http://haujournal.org/Helmreich_Waves_Slideshow_LHM_Lecture.pdf. —Ed.



of nonhumans, are the subject of my lecture today, entities that, I will claim, materialize forms of territory, property, relationality, and agency, all preoccupations of Morgan's and of contemporary anthropology.

* * *

How many waves are there in the ocean? In February of this year, at a beachside restaurant in Newcastle, Australia, Melbourne-based, Russian-born wave scientist Alexander Babanin ran me through an ink-and-paper calculation: take the mean wavelength of the dominant sort of wind-forced wave in the sea: 100 meters. Multiply that by the width of the average crest (also 100 meters) and get 10^4 square meters, the area of the average wave. Now, divide the expanse of the world ocean, 10^{16} meters square, by that wave area and get 10^{12} : a trillion waves. There, within earshot of Newcastle's surfing beach, Babanin gave me a mathematical reckoning of what Leonardo Da Vinci once called "the numberless waves of the sea."

Why would one want to tally the waves in the ocean? For scientists at the First International Australasian Conference on Wave Science (where I met Babanin), such accounting may aid in apprehending global wave weather and in projecting long-term *wave climate*. I had come to the workshop to learn the particulars by listening in on forty or so oceanographers, mathematicians, and meteorologists discussing wave modeling. I had discovered, in previous anthropological work among microbial oceanographers [SLIDE 4], that the global state of the sea can often be illumined through measures of its smallest, composing parts (Helmreich 2009). At this conference, organized by New Zealanders and Australians and playfully named Kiwi-Oz Waves, or KOZWaves [SLIDE 5]), I learned that many scientists interpret water waves (evanescent entities known through buoy and satellite measures as well as through computational models) as signs, as indices, of climate change, and, perhaps, humanly modulated climate *futures*.

Why do I take waves and wave scientists as subjects of study for my newest anthropological research? Two reasons.

First, while waves have a manifest materiality to them, they are also only apprehensible through abstractions [SLIDE 6], whether these are deployed by scientists, fisherpeople, surfers, or others; as such, waves are good to think with—and against—recent calls in social theory to attend to *materiality* [SLIDE 7: a minibibliography of iconic books on the new materialisms, the call, in recent humanities to attend to the extra- or prediscursive material world in literary and cultural accounts; you'll see underlining these books something of a snapshot from the *Zeitgeist*, a 2013 Rice University Humanities Research Center call for postdoc applications on this topic]. Such "materiality" is, I think, too often posed, particularly in post-poststructuralism, as some really real outside signification. But the materiality of the world should not, I think, be separated from the formalisms we use to describe it [SLIDE 8: images of recent books on formalism, mostly in cultural studies of literature, art, and math, again underlined by a recent humanities center postdoc call for applications, this one at Rutgers, from 2012]. And, here, just to be clear, is a formalism describing canonical water wave motion [SLIDE 9]. To carry this closer to home, let me pepper in formalisms from anthropology [SLIDE 10], diagrams that might fascinate someone like Tim Ingold, whose 2007 book *Lines* [SLIDE 11] reads the traces and threads that make up kinship diagrams, rings of exchange and communication, and other anthropological



abstractions (and I love the wavy profile, lower right, of Bourdieu's rendering of the seasonal calendar of the Kabyle, which he offers, in fact, as a warning against the hazards of formalism, though he himself never really steers fully clear of these).

The founding premise of my research is that the materiality of waves cannot be separated from the formalisms describing them [SLIDE 12]. The waves in which I am interested are *scientific things*, entities at once material and measured, concrete and conceptual, and, to borrow phrasing from the historian of science Hans Jörg Rheinberger (1997), epistemic and technical. As an anthropologist of science—someone curious about how authoritative accounts of *nature* are assembled in practice and discourse, in labs, at conferences, in scientific papers, in public culture—I wish to know how scientific formalisms (such as “the wave,” “species,” or “life”) operate to identify and even create new entities in the world. More particularly, I am curious about how people employ such hybrid onto-epistemo-forms as “waves” to think *across domains* [SLIDE 13]. My wider project asks after wave phenomena and models as described by cosmologists, cardiologists, artists, oceanographers, surfers, economists, social theorists (see, e.g., Helmreich 2013). I am interested in the analogies and disanalogies conjured across such zones as the watery, the acoustic, and the social—believing, with Marilyn Strathern, that culture, “consists in the way people draw analogies between different domains of their worlds” (1992: 47).

A second reason to study waves is to extend and query contemporary anthropological conversations about “the nonhuman” [SLIDE 14, a visual bibliography], conversations that have so far treated multispecies collectives (including insects, fungi, trees, microbes) as well as, quite recently, water, air, oil, light, mud, and rocks. Waves, as amalgams of the physical, formal, abstract, and agentive, are enticing objects with which to puzzle through what several scholars are starting to call an anthropology beyond/beside humans.

Tonight, I will speak about ocean waves and climate futures [SLIDE 15]. To best appreciate that future, we might first ask: *do ocean waves have a history?* The question may sound odd: surely waves are simple facts of nature, timeless matters of the substance of the sea. As historian of oceanography Helen Rozwadowski writes, “most glimpses out to sea reveal endless waves reaching to the horizon rather than any lasting evidence of human presence” (2010: 162). Waves may have diverse manifestations in marine and maritime lore [SLIDE 16], a variety of effects on political economic enterprise, and a range of meanings for surfers, artists, or mathematicians. But as formal and material entities, the common wisdom might go: *there they are*, more or less well captured by the scientific apparatuses—increasingly computational and Internetworked—crafted to measure and model them. For some wave scientists, however, not only are scientific modes of representing waves transforming (increasing in power, fidelity) but the patterns and shapes of waves themselves are also transmuting, as storm tracks shift closer to the poles, as the global distribution of significant wave heights begins to wobble, and (the claim is controversial) as rogue waves (waves uncharacteristically and unexpectedly larger than those immediately around them) grow in number.

In what follows, I report on debates among ocean wave scientists about whether Earth's wavescape might be transforming in synchrony with the political, economic, and social scene of the *Anthropocene* [SLIDE 17], that name ecologist Eugene Stoermer and atmospheric chemist Paul Crutzen proposed in 2000 to designate the contemporary geological epoch, dating to the Industrial Revolution, during

which human activity began to have global effects, effects now layered into a geological record marked with evidence of coal extraction, atomic testing, ocean plasification, and accompanying species extinction. Whether and how waves might be comprehended as elements in this world, primarily in association with global warming, is an open question. For wave scientists, waves materialize as events—often, *populations* of events—that may be predicted and, perhaps, managed. Waves, for these researchers, I argue, are *texts*—media that might be read for something of the planet’s future state (I note that will not speak here about tsunamis, hugely important in recent times. I follow—for now—my wave scientist interlocutors, who differentiate between wind-waves, predictable, connected to climate, and therefore to things *anthropogenic*, and tsunamis, detectable, but not predictable. I’ve written elsewhere about the Indian Ocean tsunami of 2004 [Helmreich 2006]).

Donna Haraway (2014) has lately suggested that the Anthropocene might better be named the *Capitalocene*, since so many recent geophysical transformations have followed from capital-intensive extraction of fossil fuels. She has also proposed that the collateral mess—oceanic dead zones filled with mucilage communities, new populations of jellies and slime—has muddied bright lines between evolutionary pasts and futures. Stealing a page from horror fantasist H. P. Lovecraft, Haraway suggests that eco-theory might take as its mascot *Chthulu*, the tentacled monster of Lovecraft’s repressed, abject, but potent Earth (see Lovecraft 1928). She suggests that we could call our epoch the *Chthulucene*, a heterochronic time in which the boundary between the ancient and the contemporary is mucked up [SLIDE 18].¹

1. If industrial humanity’s signature can now be read in the geological record, the fortunes of the “Anthropocene” as an increasingly hot keyword in anthropology might be charted by a look at the 2014 program of the meetings of the American Anthropological Association, which, as John Hartigan (2014) has pointed out, saw scores of appearances, up from zero in 2013.

In querying the attraction of the *Anthropocene* to scholars in critical natural and social science as well as in the humanities and arts, Haraway has lately been joined by several others committed to pointing out the not-so-hidden universalism, Eurocentrism, human exceptionalism, and—at times—androcentrism often animating the notion of the Anthropocene (see, e.g., Garrard, Handwerk, and Wilke 2014; Sloterdijk 2014). Look also to economist Kate Raworth’s October 16, 2014 tweet about the absence of women scientists on the Anthropocene Working Group: “The Anthropocene is bad enough. Spare us a Manthropocene” <https://twitter.com/KateRaworth/status/522993208650108930>; consult <http://quaternary.stratigraphy.org/workinggroups/anthropocene/> for more about the Working Group. For a critical feminist rethinking of how the contemporary geo-historical era might be imagined, see the program of the “Anthropocene Feminism” conference, held April 10–12, 2014 at the Center for 21st Century Studies (C21) at the University of Wisconsin-Milwaukee: <http://c21uwm.com/anthropocene/conference-videos/>). For a history-of-science-inspired science fiction piece that locates the causes of anthropogenic climate change in capitalism, in faulty systems of governance, and in genres of scientific method insufficiently tuned to social complexity, see Oreskes and Conway 2014. For a reading of the relation between climate change and the racialized geography of the United States that suggests that still more specificity is called for in framing the politics of recent climate history, see Smith 2014. And see Parikka’s notion of the *Anthrobscene*, explained in footnote 6.

Now, wave scientists are not so apt to fold science fictional or mythical figures into their work, but they *do* read their principal texts, waves, with a fantastical many-eyed, many-armed figure over their shoulder: namely, the *human*, at risk at individual, community, regional, and global scales and at the same scales in short-sighted denial. Waves, for wave scientists, have an anthropology inside them, an account of humanity.

I wish to sketch this anthropology, drawing out how the figure of humanity suffuses wave science. I will proceed as follows: a first section will offer a history of wave research, demonstrating how sociopolitical imperatives have long saturated knowledge in this natural science. In a second part, I will deliver a report on a wave conference I attended in Banff, Canada. That will be followed by a third section, returning to the wave workshop I attended in Australia, in which I compare wave science in the Northern and Southern hemispheres, asking whether there might be for oceanography, as Jean and John Comaroff (2011) have suggested for social analysis, something like a “theory from the south” [SLIDE 19]. If the Comaroffs contend that Northern (i.e., European and American) frames of social analysis (the “economy,” “nation,” “progress”) misapprehend the motivating forces of the world today (which they say appear most sharply in the global South, with Africa their court of appeal), I detect, among some oceanographers, a claim that thinking from southern oceans—with their greater proportion of seawater and ice—might be needed to upend the northern assumptions built into many wave models and to account for intensified ocean storms, massive coral and mangrove depletion, and sea-ice breakup: southern-sea processes with planetary effects.

A word on method: My ethnography comes from scientific conferences [SLIDE 20], sites that, as an anthropologist of science, I have learned to turn to in order to discern what count as settled questions and live debates in scientific fields. Conferences are, to borrow a term from Victor Turner (1957), social dramas, moments when a community makes explicit to itself historical rivalries, present puzzles, possible futures. As I continue fieldwork, I intend to join wave scientists on their ships, in their labs, and at their computers. I am happy to entertain questions about such plans later on, though, as you’ll hear as I sum up, after my third part, my questions will be more about the relation between natural and cultural history, and, using the work of Dipesh Chakrabarty (2012), about relations among history, science, and anthropology.

So: to history.

A compressed history of wave science

How have waves in the sea come to be modeled in a systematic way, for weather, ship design, coastal management [SLIDE 21]? The first oceanographic accounts of waves arrive from nineteenth-century imperatives in Europe and the United States to know the sea as a site for the extension of land-based activities: shipping, colonial travel, warfare, and communication, including networked undersea cables of the kind Nicole Starosielski writes of in her forthcoming book, *The undersea network*.² Well before computers and networked buoy systems, even into the twentieth

2. Oceanographic science in general was bound up with American expansionist and British imperial enterprise. For a classic history, see Schlee 1973. For a more recent

century, wave information was often gathered in the midst of the sea itself, as in these photos from the 1940s, of Willard Bascom measuring waves with a ruler [SLIDE 22]. Bascom wrote of one big wave: “While balancing under this incipient waterfall, I would estimate the height of the wave that was about to come crashing down, add one third of that . . . to the trough depth, call the answer into a microphone, and duck” (1988: 9). World War II was a turning point. Bascom works here on a duck boat, the sort of amphibious military craft that landed allied troops at Normandy on June 3, 1944 (D-Day) and for which many wave models were developed. Walter Munk and colleagues at Scripps Oceanographic in San Diego [SLIDE 23] edged wave science into the realm of big science, working more abstractly, from data gathered at local beaches, international wave-reporting stations, and (this was new) views from airplanes (see Sverdrup and Munk 1943; Schlee 1973). Representations of waves from on high, argues feminist theorist Tara Rodgers (2009), were in the nineteenth-century commentaries of scientists such as John Tyndall and Hermann von Helmholtz often coupled with rhetorics of using calculation to tame a feminized flux into order. An objectifying God’s eye view *is* part of the twentieth-century tale, but more is in motion, too. Bascom’s outdoorsy being-in-the-wave masculinity also roils into repertoires for gendering the sea.

After World War II, wave science continued as a large-scale institutional activity. Military research during the detonation of nuclear weapons in the south Pacific [SLIDE 24] generated waves we could nominate as *Anthropocenic*, human-generated shock waves that travel faster than their medium, water, can carry them (see Rainger 2004). Coastal infrastructure called for new developments in wave science, as did offshore oil drilling [SLIDE 25], that practice sociologist Jackie Orr (2013) has described as the release of a viscous inhuman intelligence, an emissary, perhaps, of the Chthulucene. Wave science came into maturity with sociopolitical economic imperatives, and in the United States, was keyed to projects of mass society: military, urban, coastal.

A key inflection point came in 1961, with the invention of the *wave power spectrum* [SLIDE 26] (see Irvine 2002). In this mathematical model, waves are known not as individuals but as collections of superimposed waves, little and big, with different origins. A “wave” might be made up of forces churned up by a hurricane a week ago, as well as by fresh energy from wind-swept ripples. Waves are rendered not as wavy side views of undulating water [SLIDE 23], but as collisions of bell curves. Oceanographers come to speak of “wave systems,” and the sea becomes statistical (and so, what political scientist Philip Steinberg [2001] has analyzed as a European model of the ocean as a “great void” or blank space between nations continues, with wave science—as it had begun with wind charts in the nineteenth century—to acquire a surface texture).

As waves become statistical, they begin to look like their contemporaneous social world, newly conceptualized, as Sarah Igo (2008) writes in *The averaged American*, as an aggregate of probabilistic social phenomena (birth rates, income levels, more). No surprise that Elias Canetti in his *Crowds and power* [SLIDE 27] makes

history of science account, see Reidy and Rozwadoski 2014. On tides, see Reidy 2008. On currents, see Mills 2009. For a more detailed history of ocean wave science, see Helmreich, forthcoming.



a link between the sea and the social: “The sea is multiple, it moves, and it is dense and cohesive. Its multiplicity lies in its waves. . . . The dense coherence of the waves is something which men [sic] in a crowd know well” ([1960] 1984: 80).

Let me bring you up to speed on how wave scientists nowadays understand the formation of ocean waves: it begins with the sun heating the Earth, driving air pressure changes. This creates wind [SLIDE 28], initiating waves, transferring energy from air to sea. Persistent wind across an area of water, a “fetch” of *windsea*, generates waves with a predictable range of heights. Out from under the influence of wind, waves are called “swells,” packets of energy that continue to travel, and move in groups, sets, trains. *Significant wave height*, the average of the tallest 1/3 of waves in an area, is picked out through wave spectra. Like many scientific things, waves are empirical and conceptual. No surprise, though, that such epistemic hybrids once made scientists nervous, even founding figure Walter Munk: “Inasmuch as these terms—‘fetches,’ ‘finite durations’—are really great idealizations of the wind field over the sea, to try and write spectra for given fetches and finite durations is to endow these meteorological notions with more claim to reality than they deserve” (quoted in Irvine 2002: 380). So, while waves are material, they are also abstractions that take form depending on how oscillation is conceived, observed, modeled. For real world ocean waves, *that* depends on *infrastructure*, networks of buoys, satellites, computer models.

In the 2010s, waves are largely measured by buoys, created, owned, and operated by a collage of governments, companies, and other agencies [SLIDE 29: map from US National Data Buoy Center; SLIDE 30: page for buoy closest to Rochester, on Lake Ontario; SLIDE 31 webcam for buoy off Santa Barbara; SLIDE 32: wave buoy data on a phone]. The data buoys gather are telemetered to computers that host models predicting swells and surges, models such as WAVEWATCH III, operated by the US National Weather Service [SLIDE 33]. There are other models, too, created, owned, or consulted by meteorological organizations, shipping companies, coastal infrastructure planners, fishers, boaters, surfers. What portrait of the world wavescape is conjured through this mosaic? How would one start to answer this question?

Dangerous sea states

I started in the Canadian Rockies, at an October 2013 conference in Banff, Alberta: the 13th International Workshop on Wave Hindcasting and Forecasting, “Dangerous Sea States” [SLIDE 34]. There were eightyish participants, mostly from the United States, Canada, France, Germany, the United Kingdom, Australia, and Japan, though a handful from such places as Mexico and Malaysia. Oceanographers, mathematicians, oil industry people, government meteorologists, all met to consider how to model and manage hazardous wave activity, particularly the kind on the rise with climate change, including storm surges consequent upon hurricanes. The workshop began, organizers observed, on the anniversary of Hurricane Sandy, which brought so much devastation to New York and New Jersey.

The workshop was inaugurated with a talk entitled, “Are wave measurements actually ground truth?” [SLIDE 35]. Val Swail, Manager of the Climate Data and Analysis Section, Environment Canada, inventoried buoys measuring waves in the

world's oceans [SLIDE 36]. Looking at this dizzying array of devices, Swail advised his audience, with a good-humored world-weariness, "You need to define what a wave *is* before you can measure it. Is your device measuring whitecaps, foam, green water, blue water?" And in which *direction* are you measuring? Given that a typical buoy costs around \$60,000, it's worth some thought! One person joked that the "Directional Waverider" [SLIDE 37], outfitted with an accelerometer to measure the changing speed of waves, doesn't always track which way is *up*, "so that if you gave it a lateral push, it might tell you you've got a 30 meter wave!" Swail's question, "How to 'ground truth' the 'ground truth'" about waves [SLIDE 36] was a lovely mixed metaphor, a phrasing that makes clear what practitioners are after: a point in the ocean that stays still [SLIDE 38]. Computer models of wave dynamics assume a stationary sea, and a lot of work goes into factoring out the pitch, yaw, and roll of buoys so wave data can be delivered as oscillation against a fixed baseline. As historian of computing Paul Edwards argues in *A vast machine*, his history of climate modeling, "data are never an abstraction, never just 'out there.' . . . Data remain a human creation, and they are always material. Every interface between one data process and another—collecting, recording, transmitting, receiving, correcting, storing—has a cost in time, effort, and potential error: data friction" (2010: 109). As media theorist Lisa Gitelman (2013) has it "'raw' data is an oxymoron."

These are matters empirical and epistemic, as the next speaker made clear. Elzbieta Bitner-Gregersen, working for Extreme Seas, a European university consortium dedicated to ship safety design, said there were two kinds of uncertainty in wave measurements: *physical* and *epistemic* [SLIDE 39]. Epistemic includes data, statistical, model, and climatic uncertainty. *Waves, I was beginning to see, flicker, for these scientists, between reality and representation.*³ Waves are mash-ups, amalgams of watery events, instrumented captures of those events, and mathematical portraits of those events, often described statistically rather than singularly. "Obviously you cannot simulate every wave in the ocean," one researcher advised me. If, as Alexander Babanin put it in Australia, "Wind generated waves are the most complicated objects in the universe—probably more complex than objects in astrophysics,"⁴ waves are *also* complex social objects, nonhumans at once amorphous, approximated, parameterized, computerized. Mathematical representations of waves in equations [SLIDE 40] are concretized in how buoys are built, in how models incorporate data. Waves are physical and cultural objects.

Once waves-as-data are collected (transmitted from buoys, which have their own Internet Protocol addresses) they are fed into computer models like WAVE-WATCH III [SLIDE 41], a platform for forecasting futures and hindcasting pasts. Wave data can also be rematerialized in real and simulated water tanks [SLIDE 42], suggesting that waves are *media* (and I might mention the fantastic work of Eva

3. For a literary evocation of this doubleness, read Italo Calvino's "Reading a wave," a segment within a chapter of his final novel, *Mr. Palomar* (1983), in which the title character "attempts to see and describe and kidnap into language the exact nature of a single wave" (Heaney 1985).
4. Babanin is the author of a key text on ocean waves, *Breaking and dissipation of ocean surface waves*, from 2011. Other books upon which I depended in putting together this lecture include Janssen 2004; Holthuijsen 2007; Parker 2010; and Zirker 2013.



Hayward [2010] and Melody Jue [2014], who have theorized water—in aquaria, in art installations—as a media technology). But waves-as-data don't just get piped into models. Buoys are *political* objects, inside jurisdictions. In the United States, waves have been officially considered part of the *weather* since 1973, when the UN ratified the Convention for the Safety of Life at Sea, which tasked national *meteorological* rather than *oceanographic* agencies with wave measurement. If you want to get US data about waves, consult the National Weather Service, not the National Ocean Service (though neither will do you much good if there's a government shut-down, as there was before Banff, which meant US waves were . . . closed). One conferee told me it was a nightmare to get wave data out of the European Union: “Europe is the worst in that respect because they’ll make *some* of the data available but they’ll keep the rest because they think it has some commercial value, and so, well, we’re not gonna *give* this away because we can *sell* this instead,” to shipping companies, for example. Waves also have legal lives; one speaker reported, that for the World Meteorological Organization “only windsea and two swells are regulated in ship reports” [SLIDE 43: an image of layered wave spectrum analyses over a map of the Pacific, picking out only the legally necessary aspects of waves]. So: waves are phenomenological-technical-mathematical-political-*legal* objects. Sometimes they are carried into legal grey areas, as when pirates pillage buoys for parts [SLIDE 44].

Computerized wave models go back to the 1960s. Built on millions of lines of FORTRAN, such programs are similar to the General Circulation models upon which the Intergovernmental Panel on Climate Change (IPCC) depends. They run on an armada of supercomputers [SLIDE 45], which need huge amounts of air conditioning, contributing, wave scientists wryly emphasized to me, to the very carbon profile they are tasked with tracking.⁵ As computationally intensive as they are, wave models often demand *more* data points than there are buoys. When that is so, models can conjure proxy data points—virtual buoys created by interpolating between known data points. Such simulated ghost buoys—making “waves” in the “cloud” (that is, in remote computer network servers)—speed up prediction. One speaker explained how her team models storm surges: “We have developed 1500 possible, simulated, storms. When there’s a storm coming, we look through our catalog of possible storms and find a match—or develop a stochastic, statistical prediction—which we can do quickly since it only takes a second to run a scenario.” Real data can take 2000 hours to process.

Virtual waves make some people uneasy. Two buoy developers, who started out as fishermen, grumbled to me at the storm talk, “That’s not data. That’s made up.” One ship designer made it clear he didn’t care about waves as such, only about whether his ships had hulls that would resonate dangerously with certain wavelengths [SLIDE 46].

5. In that sense, these computers and their virtual waves may be part of what Jussi Parikka (2014) calls the *Anthrobscene*—the toxic material accompaniment of contemporary computational, tablet, and smartphone media culture, which, far from ushering the contemporary world into a “paperless” ecotopian sublime, fills the world with toxins consequent on producing, consuming, and discarding the devices that permit (some) people to make global assessments at all.

The figure of humanity—individual, corporate, regional, global—saturates this science. That became visceral as news streamed into the conference of St. Jude, an extratropical cyclone that arrived in northern Europe on 27 October and killed seventeen. Just hours into the workshop, a presenter showed the day's headline from *The mail*. England was being “lashed by 25ft waves.” [SLIDE 47] Participants from the European Centre for Medium-Range Weather Forecasts were gratified their models seemed to be predicting the path, though were upset about people heading out to the waves anyway. “We can't save everyone!” one participant exclaimed at a picture of a kite surfer. Everyone moaned at the story of a 14-year old swept out to sea. Talk of probability becomes talk of *risk* when human elements are introduced, one speaker remarked.

Such attention to individual humans contrasted with talks about populations of coastal dwellers. Conversation turned to storm surges, what one speaker called “the stupid big brothers of waves.” It was here that differences between nation-states differently positioned geopolitically—in the global North and the global South—emerged as a topic. UK scientist Matt Lewis spoke about the World Meteorological Organization's Coastal Inundation Forecasting Demonstration Project, aimed at improving forecasts for such places as Bangladesh, a low-lying country with a history of storm surges that have killed hundreds of thousands of people. He commented that it is hard to “get data into a model” for such settings because they are “data poor” [SLIDE 48], not dotted with measurement instruments. More, surge models imported from elsewhere don't work; the mangrove forests and dense coastal villages of Bangladesh are not written into off-the-shelf models. Facts-on-the-ground vary, and change.

Open-ocean and hemispheric dynamics don't stay still *either*. I found a dramatic, global picture on a conference poster [SLIDE 49, 50]. Lured in by lustrously colored maps of world seas, I found Portuguese oceanographer Alvaro Semedo explaining future *wave climate*. He had taken global data about significant wave heights from the present, defined as 1959–1990, and then, assuming a steady increase of CO₂ into the atmosphere—the IPCC's *anthropogenic scenario*—projected significant wave heights into the future, 2069–2100. Prognosis? Climate change will generate larger significant wave heights in the southern oceans [red], which will correlate with more extreme weather—storms, droughts—and with an accelerated breaking-up, by wave action, of Antarctic ice. An Australian wave scientist, animatedly joining in, remarked that *Homo sapiens* were driving the planet toward disaster: heat waves in Australia, floods in south Asia, collapsing agricultural infrastructure in Africa, waves, he said, of climate refugees; it was impossible, he complained, to get politicians to think geophysically: “Politicians don't understand physics, and physics doesn't recognize politicians.” “Yes,” another scientist chimed in, “that's the thing: weather and waves don't recognize borders!”

Suddenly, I was an anthropologist in the *Anthropocene*, with human agents and destinations for thinking about global climate, with climate a process at once natural and historical. Literary theorist Ian Baucom, extending historian Dipesh Chakrabarty's noted division of history into two kinds—[SLIDE 51] History 1 (normative, secular, Enlightenment history, as told by the West) and History 2 (subaltern, post-colonial, sometimes supernatural accounts)—has proposed that climate change might require a new history: History 3, *naturalhistorical* (Baucom 2014; and see



Chakrabarty 2000, 2012. Consult, too, the argument made by Bruno Latour [2014] that the frame of the Anthropocene demands not only history but also *geostory*). Baucom has also called for History 4°C, keyed to the temperature rise projected for the next century. Maybe Semedo's image [SLIDE 50] is one visual aid for that. Talking about things *Anthropocenic* with the scientists gathered around this poster (my being an anthropologist now an authorizing rather than a “what-are-you-doing-here?” identity) saw me chatting with them about how north Atlantic hopes for wave energy might founder if wave heights decreased, how coastal infrastructures might drown, how shipping routes might go haywire. Soon we were all Anthropocentrically indignant.

I asked about a claim I heard about *rogue waves*, statistically unexpected waves, defined as twice the significant wave height of their surrounds. Elzbieta Bitner-Gregersen of Extreme Seas had argued that bigger storms in southern oceans might lead to increases in rogue waves [SLIDE 52]. My interlocutors were divided on that claim, though all believed such waves existed. Whereas, once upon a time, rogue waves were considered mythical, conjured by credulous mariners, they are now accepted as real, though their rate of incidence is unknown. In 1995 came the first measured instance, at a North Sea Norwegian gas pipeline-monitoring platform, the Draupner [SLIDE 53]. In a field that treats waves as statistics, this one was given an individual name: the Draupner wave (though in this image it's being played by 1829 Japanese woodblock print, *Great Wave off Kanagawa*, which seems to be the go-to clip art for large waves). What causes such waves? They may emerge from the superimposition of waves in “crossing seas,” [SLIDE 54] from wave-current interactions (Africa's Cape of Good Hope is notorious), or from resonance events in which one wave sucks energy from another, a process described using the nonlinear Schrödinger equation, from quantum mechanics. Bitner-Gregersen said, “we can expect that in some ocean areas, where the wind severity increases, and we get more ‘crossing seas,’ we will see more rogue waves.”

Here, rogue waves become more than epistemologically novel; they become ontologically new, amplified. They appear, too, as *characters* in an Anthropocene drama, nonhuman actors created by global humanity's geophysical agency. Chakrabarty suggests that the Anthropocene *doubles* the figure of the human, placing embodied humans alongside the Human, capital H, a scaled-up actor with inhuman capacities, such as the initiation of global warming. Rogue waves, then, are specters, materializations of the inhuman human. They are not like those breaking waves that were, for early Christians, a sign of God's beneficence. St. Basil [SLIDE 55] wrote that at the moment when the sea meets the land, it “withdraws out of respect, *bowing its waves*, as if to worship the Lord who has appointed its limits” (quoted in Corbin 1995: 26–27). That's a History 2 wave, supernatural. Neither are such waves emissaries of unrepentant modernity, as for Nietzsche ([1887] 1974) in *The gay science* [SLIDE 56]: “How greedily this wave approaches, as if it were after something! How it crawls with terrifying haste into the inmost nooks of this labyrinthine cliff! But already another wave is approaching, still more greedily and savagely than the first, and its soul, too, seems to be full of secrets and the lust to dig up treasures” (247). These waves are not, either, like the wave of Octavio Paz's 1949 short story “My life with the wave” [SLIDE 57], a wave the protagonist takes home, a tempestuous seductresses that might be tamed in a mermasculine heterosexual

conquest. No, rogue waves [SLIDE 58] are of our historical moment; like the rogue states of which their name must remind us, they are *just* large and unpredictable enough to disturb institutional business as usual. They are part of human worlds, never accessible outside cultural meaning, no matter what new materialists say. The possibility that they emerge most strongly in the South gets me to my next episode.

Wave theory from the South

I return in this final third of this lecture to where I began, at Kiwi-Oz Waves: the First Australasian wave conference [SLIDE 59]. I was drawn here by the words *first* and *Australasian*. Now, I certainly did not expect a shot-across-the-bow postcolonial, subaltern studies take-down of northern hemispheric presumptions embedded in computational wave models, a call for wave modeling to be turned upside down, like a counterideological south-up map [SLIDE 60]. And, anyway, Australia, that is to say, Euro-Australia, is hardly a distinct science community, especially at this workshop since, in spite of the conference name, no one, with the exception of one postdoctoral fellow from Iran, had any academic base in Asia. With scholars from France, Germany, and the United Kingdom, this was a cross-equatorial eddy from the North.

Still, there *was* a keen sense that southern ocean dynamics were underrepresented. One European model had been found to underestimate wave heights by 20 percent in the southern hemisphere (see Janssen 2000). Just after the workshop, *Nature climate change* [SLIDE 61] published on mis-estimations of southern ocean sea surface temperatures in most climate models, the result of assuming too-low cloud cover over southern seas (Wang et al. 2014), a topic at another conference, where one might indeed get wave theory from the South: The International Conference on Southern Hemisphere Meteorology and Oceanography [SLIDE 62].

What other elements make a difference in modeling waves in the southern hemisphere? An Australian meteorologist rattled off to me four major distinctions between southern and northern hemispheres [SLIDE 63]. First, there is more solar radiation hitting the sea in the south than the north; this part of the Earth is closer to the sun most of the time. Second, there's a *lot* more ocean, uninterrupted, in the south, which means the proportion of the ocean suffused by *swells*—waves no longer driven by wind—is much higher. Third, there's less particulate plant matter in the near-sea atmosphere because there's less land. Fourth, there is a larger area of *ice* in southern oceans. This meteorologist put it bluntly: "Northern hemispheric assumptions are *built right in* to the models, including of waves. That makes them challenging to use in the southern hemisphere."

But Northern hemispheric assumptions are hard to tease out; southern oceans are less heavily instrumented than northern ones. One conferee recounted a visit to Miami, "If you're in the northern hemisphere, and they tell you that the wave front will come in at 4:30, it will come in at 4:30. If you're in Australia and they say it will come in at 4:30, it might come in tomorrow." There's a geopolitical reason; among the larger coastal nations that might manage such systems—India, South Africa, Brazil, Argentina, Chile, Indonesia—there has not been a highly state-funded capitalized maritime infrastructure. Even Australia is ringed by only twenty-five buoys



(the United States monitors 200, which, most complain, is still too few). Satellite data can sometimes, though not always, substitute.

Jean and John Comaroff write, of that zone known these days as “the global South,” that its geographies have been treated in social theory as “a place of parochial wisdom, of antiquarian traditions, of exotic ways and means,” and, “above all, of unprocessed data . . . reservoirs of raw fact” (2011: 1). One might say that, in oceanography, the southern hemisphere has been similarly construed, a zone of “unprocessed data,” though much of the data hasn’t been gathered yet! What *kind* of data to collect—about open-ocean wave action, about the wave-agitated breakup of Antarctic ice, about storm surges in low-lying south Asian countries—is an ongoing, political question.

What happens when models from one sea are transposed from one sea to another? Practitioners worry a good deal about such “regional tuning.” But the boundary between fundamentals and “tuning” is not laser clear. Sometimes tuning means incorporating regional measures, sometimes tweaking algebraic parameters to yield the right values: *fudging*, some uncharitably say. Several talks featured extensive detail on such tuning. At one point, smiling to a couple of scientists who told me that hearing such talks was for them “like having a drill held to your head,” I stepped out to the Newcastle Art Museum, a block away, which turned out to have an exhibit of paintings and sculptures of waves [SLIDE 64]. When I showed postcards of these works to one scientist—he’d been too busy to squeeze a museum into his day—he judged them as he would a wave model hastily tuned: “that painting is missing the whole water column, this is just the surface feature.” He had unkind words for the sculpture: “It’s like it’s done by a child. Waves do not break like that.” What was true of the art was also true of science: “when you represent what a wave is, you can only do it partially.”

Let me give an example of partiality in tuning a model, an example not from south of the equator, though from a country south of dominant centers of wave modeling: Iran (Saket 2014). An Iranian scientist described the challenges of characterizing a part of the Gulf of Oman known as the Chabahar zone [SLIDE 65]. Iran wants to harness waves here for electricity but needs more information. Unlike the Persian Gulf, the Gulf of Oman has poor buoy coverage. This scientist worked with data he could get, plugging this into a model of wave action called SWAN (Simulating Waves Nearshore); he didn’t use WAVEWATCH not only because it is better for open ocean, but also because trade embargoes prevent it being exported from the United States to Iran. He needed a recipe for simulated wind, and borrowed from a European model. It didn’t work. What happened? Babanin helped me figure it out: “Wave models traditionally are validated by means of observations and that’s always through some geographically linked observations. Satellites are global, but buoys are definitely regional, so if there is anything in your region and you tune your model to perform well in this region, then if you take it to another region where certain things are different, it can have biases.” In this Gulf of Oman case, average wind-speeds from the North Sea, to which European models tuned, were different from Gulf wind-speeds. This was a natural-scientific iteration of what Chakrabarty names as the logic of universal knowledge, which, for social sciences, have often claimed *First in Europe, then elsewhere*, with Europe, now, not so much a full-blown ideological referent but a set of tiny technical details.

The most striking southern hemispheric angle on wave science came in talks on Antarctica [SLIDE 66]. Not only is there less ice in the Antarctic than a few decades ago, its character has changed. Storm waves have fractured pack ice, breaking it into tiny ice floes. More than one speaker told harrowing stories of standing on floes, attaching wave-measuring accelerometers [see upper left image on SLIDE 66], when things got cracky. These scientists routed their sense of the global through bodied experience. One commented that fieldwork on ice made global processes more “real” to him, “visceral.” A few used their bodies to mime wave action, reminding me of science studies scholar Natasha Myers’ observations of molecular biologists who use gestural motion to get a “feel” for how proteins fold (2008). The relay between inhuman and human is scaled through sensory substance and sentiment.

Accelerating ice-melt will affect everything from ocean circulation to coastal upwellings of nutrients. New modeling tools are called for. As one scientist put it, “If you take parameters from the Northern Ocean, they don’t necessarily apply to the Southern Ocean. Who *cares* about the Southern Ocean, except us? But people will start caring if it affects global climate!” Funding for wave modeling in Antarctic settings is on the rise, and scientists in Australia are well positioned to access the continent, which place anthropologist Jessica O’Reilly (forthcoming) in *Technocratic* wilderness observes has been reinvented many times as a site of extreme futures. The wave theory from the South emerging at this conference was just one among many. If you saw the *New York Times* earlier this year, you could think of a wave theory from the South as one focusing on storm surges in countries open to southern hemisphere cyclones, like Bangladesh or the Philippines [SLIDE 67]. As I continue this project, I seek to tune to the multiplicity of possible waves that could be the subject of such theory.

The last wave

On my way back to Boston, I traveled through Sydney, and at the city’s Maritime Museum saw an exhibit about Northern aboriginal maps of sea country, bark paintings created in the 1990s as legal documents to shore up Yonglu claims to sea space (see Buku-Larrnggay Mulka Centre 1999), like this one [SLIDE 68], which maps “water . . . in country around the mouth of the Baraitja River.” Territories of different clan moieties are marked with distinct designs. Although one might see in these lines something like waves, something else hit me. At the exhibit’s entrance was a “cultural warning” for Aboriginal museumgoers, cautioning that names of deceased artists were recorded next to some paintings; Aboriginal prohibitions against naming the recently dead, the warning urged, might make the exhibit upsetting.

An anthropologist schooled in Aboriginal studies might ask how models of humanness as relational multispecies personhood weave into watery images such as this (see, e.g., Rose 2012). Alternatively, one might, with Elizabeth Povinelli (2002), point to these as tactical representations in an Aboriginal politics of recognition. As an anthropologist of science, this painting prompted me rather to consider how models of humanness were folded into the models I’d heard about in Newcastle. On beyond the fact that the wave conference had at its center Chakrabarty’s doubled human (embodied humans at risk, capital H humanity to



blame) the workshop was, like the bark painting exhibit, crowded with the names of the deceased: Laplace, Kelvin, Bernoulli, Euler, Fourier, those eighteenth- and nineteenth-century mathematicians whose names are remembered in the equations of wave science [SLIDE 69].

What is a wave? I said before that waves are phenomenological-instrument-data-model hybrids, but—at least for waves described by equations—a wave is also a trace of a social history, a trace, perhaps, of History 1, the Enlightenment historicism contemporaneous with the calculus. Perhaps, however, such waves also, given the religious struggles of many European mathematicians, contain echoes of History 2; ideas about infinitesimals, when first developed, were controversial for the Catholic church, which feared that indivisibles placed paradoxes at the heart of God's creation, confusing matter with its measure (Alexander 2014). Kelvin, a contemporary of Morgan's, was an old-earth creationist, and his numbers gave him twenty million years as the age of the planet. The waves of wave science have people, biographies, inside them. And not all are hermetically sealed European stories. When it comes to knowledge about ocean waves, we know such figures as Captain Cook were in dialogue with navigators from other traditions (Mack 2011); the Polynesian navigator Tupaia is one example [SLIDE 70: this is Tupaia's Pacific map, using wind and current to mark distance. I felt it incumbent upon me to at least gesture toward another Oceanic mapping tradition—Marshallese wave navigation stick charts used to plan navigation around Micronesia; these are late nineteenth-century examples]. As the Comaroffs write, “modernity was, almost from the start, a north-south collaboration—indeed, a world-historical production—albeit a sharply asymmetrical one. . . . It has always been a composite of multiple signification, materializations, and temporalities” (2011: 6). I asked at the outset of this paper if waves had a history, and I hope I persuaded you that they also have an anthropology; they are artifacts that materialize territories, properties, relations, agencies.

I'll close in Sydney, with another wave, *The last wave*, a 1977 film [SLIDE 71] directed by Peter Weir, about a white lawyer contracted to defend four Aboriginal men in Australian court. As the lawyer is drawn into the world of his clients, he is haunted by visions of, and perhaps even sees, it's not clear (it might be an apparition from the Dreamtime), a tremendous wave coming to wipe out Australia. The wave symbolizes the power of the sea to destroy human enterprise, but also the crashing disaster of colonial dispossession and the return to the colonial power of the repressed, perhaps Chakrabarty's History 3 carrying a communication to History 1 about its disavowed but always turbulently present, History 2s. Wave science today is similarly multiple, emergent from a multitude of histories and agencies, norths and souths, natures and cultures, nonhumans and humans. In the Anthropocene, wave science is anthropology by other means.

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