UNIVERSITY OF CALIFORNIA

Los Angeles

Making Climate Knowledge Actionable:

Risk, Uncertainty, and the Politics of Protection in a Warming World

A dissertation submitted in partial satisfaction of the

requirements for the degree of Doctor of Philosophy

in Sociology

by

Ian Gray

2021

ABSTACT OF THE DISSERTATION

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Risk, Uncertainty, and the Politics of Protection in a Warming World

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Doctor of Philosophy in Sociology

University of California, Los Angeles, 2021

Professor Stefan Timmermans, Co-Chair

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In this dissertation, I examine how information about the impacts of climate change becomes tractable for both administrative and economic processes of decision-making and valuation. I look at the policy and knowledge networks, devices, formulas, protocols, negotiations and contestations that shape the conditions in which public and private-sector actors incorporate and translate the notion that, as future climates drift from their historical pasts, assumptions about the dependability and stability of weather, natural resource availability and the broader environment in which modern societies have flourished become less and less tenable. Structured around three qualitative cases, each chapter of the dissertation sheds light on how efforts to calculate the physical consequences of climate change are reconfiguring institutional relations in catastrophe insurance, public water management, and state-led coastal wetland protection. Besides foregrounding the social construction of translational networks of decision-making, this dissertation also seeks to answer a central puzzle about institutional innovation – how do

organizations make decisions in the face of operational uncertainty, especially when that uncertainty regards the behavior of the physical environment upon which an organization depends? Furthermore, how do uncertainties regarding changes to the behavior of the environment themselves operate across institutional boundaries and affect the strategic positions and relations of institutionally connected actors?

By bringing attention to the nitty-gritty work being done by specific actors interested in translating science into action (frequently through specific, climate-enhanced decision-making devices), my research combines concepts and methods from the sociology of science and technology, political studies of organizational life, and cultural notions of institutional action. Drawing on insights across the three cases, I provide a general theoretical framing for the conditions by which scientific knowledge gets enrolled in processes of institutional governance and transformed into "actionable information". Actionability, in my cases, is about articulating knowledge and data produced by climate scientists with the particular processes of risk evaluation and risk management that administrative and economic actors use to assist in deciding whether to renew insurance contracts, how to ration dwindling common resources, and where to invest public money in protective infrastructure. In each of these cases, unintended consequences of this actionability reveals the urgent need to develop new theories of institutional change that account for how climate change provokes field-level disruptions that challenge our collective capacity to provide for equitable forms of climate adaptation and protection.

The dissertation of Ian Gray is approved.

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2021

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Acknowledgements

This dissertation is the fruit of a great number of influences and experiences over the years, both professionally and academically. I lucked out immensely to end up at UCLA, thanks largely to Stefan Timmermans, who lauded the collegiality of the sociology department's academic community, the commitment of its faculty to training graduate students, and assured me I would have plenty of freedom to pursue my own version of a dissertation. He was right on all accounts. Stefan's ability to give attention to the smallest details of my work, from the draft of a struggling conference presentation to the formatting of a fellowship application, all while keeping the bigger intellectual picture in mind, are skills that he shared with immense generosity.

Ed Walker was also unfailingly available and on-point as the other co-director of my dissertation. Always ready to "try on" half-backed arguments and hypotheses, Ed deployed a special talent for pushing my ideas around, testing them from multiple sociological perspectives. He did more than anyone to help me map the subfields of the discipline and connect my interests with audiences I would not have initially identified. His deep familiarity with the literature in economic sociology, organizational studies, and social movements had an enormous role in shaping my approach to climate change from the perspective of institutional change, and in believing that understanding social institutions could benefit by paying more attention to environmental issues. Both Stefan and Ed are the kinds academic mentors I aspire to become.

Other faculty at UCLA added to my faith that it was okay to not fit entirely into a single disciplinary box, indeed that some of the best research happens between boxes, and this includes Hannah Landecker, Chris Kelty, Jacob Foster, Ted Porter, Jack Katz, and Stefan Bargheer. Many of my graduate peers, including Neal Gong, Zach Griffen, Sara Johnsen, Isaac Jilbert, Andrew

Le, Drew Malmuth, Kyle Nelson, Yotala Oszkay Febres-Cordero, Ian Peacock, Chris Rea, J Shim, Michael Siciliano, Eleni Skaperdas, and Gabriel Suchodolski, provided stimulating conversation, encouragement, feedback, and critique in various guises and encounters. A much-needed non-academic outlet came for me through the rock-climbing community at the Stronghold Gym in east Los Angeles, where Bob, Gerry, Maxime, Brent, Zach, and owners Peter and Kate all helped me expand my connection to rocks, wild spaces, and embodied forms of risk.

During the course of my dissertation, I had the great luck to be invited to the Max Planck Institute for the History of Science (MPIWG), in Berlin, where I joined the Group on Anthropocene Transformations as a visiting doctoral fellow for a couple years. Director Jurgen Renn's prodigious organizing, programmatic vision, and convening skills, along with the intellectual comradeship of Christoph Rosol, Tom Turnbull, Guilia Rispoli, and others helped me plug my work into a broader framework of Anthropocene-related research occurring across the humanities and social sciences. Were it not for support from the MPIWG, the last chapter of this dissertation would not have occurred.

A huge debt of gratitude also goes to all the people whose voices, expertise, and experiences of the front-end impacts of our changing climate fill the pages of this dissertation. Largely anonymous, except for the interviews and observations gathered for the Chapter 3, I would not have been able to pursue any of the analyses herein disclosed without their willingness to share what are often difficult, complex, and even troubling topics. I hope I've done their stories and understandings justice.

Outside these most recent academic relations, special thanks are also deserved for a number of scholars whose work and mentorship helped convince me to pursue a PhD after I finished a Master in City Planning at MIT's Department of Urban Studies and Planning. These

include Susan Silbey, Sheila Jasanoff, Stefan Helmreich, and JoAnn Carmin. In many ways, JoAnn's work was far ahead of the curve on raising questions about how societies would achieve equitable climate adaptation, and I feel I'm still catching up to the trail she was blazing before she sadly passed a number of years ago.

Numerous friends and family helped keep me steady and sane through the long grind of the dissertation. Those I spoke to most about the process, and who provided a sounding board, a distraction, or the occasional (and much-needed) adventure, include Shiben Banerji, James Burns, David Elmaleh, Andy Heisel, Nick Horton, Travis Kavulla, Pejk Malinovski, Romain Martin, Kara Oehler, Thibault Peyronel, Seth Pipkin, Jesse Shapins, and many others who I hope will forgive me if I've forgotten them here. In addition to these friends, my family has always provided inspiration for me to work on the problems I work on. My brothers, Jason and Spencer, are each deeply engaged in combatting catastrophic climate change, both working very concretely in their respective fields on decarbonizing the economy via regulatory power and market actions. Their insights into the inner workings of bureaucracy, legislation, and market constraints are a constant source of reality check on my own thinking and critiques. Without our parents, Randy and Nora, I don't know how any of this dissertation would have been possible. They have always had my back, no questions asked, and have given me the confidence to make my own way in the world.

Finally, the *dernières remerciements* go to my partner and co-pilot, Fanny Gribenski. Her humor, patience, empathy, and care have erased many a slow and frustrating day of scholarship, keeping a most-healthy perspective on this crazy mode of life that is modern academics. She shares credit for any freshness and lightness of thought in the pages that follow. As for any errors and poorly-appointed phrases, those are fully my own.

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Venturini, Tommaso, Nicholas Baya-Lafitte, Jean-Philippe Cointet, Ian Gray, Vinciane Zabban, Kari de Pryck. 2014. "Three Maps and Three Misunderstandings: A Digital Map of Climate Diplomacy." *Big Data and Society* 1(1), 1-19.

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Fellowships and Awards

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International Dissertation Research Fellowship ($26,000; 2019-2020)
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Chapter 1

Introduction – Actionability and the Politics of Climate Protection

In this dissertation, I examine how information about the impacts of climate change become tractable for both economic and administrative processes of decision-making. Across three separate but interrelated cases, I follow the knowledge networks, policy devices, material artefacts, and social negotiations that influence how public and private-sector actors grapple with the notion that future climates will resemble less and less those of the past. As a result, assumptions about the predictability of the weather, availability of natural resources, and broader environmental stability around which modern societies have evolved will be subject to increasing uncertainty, disruption and failure. Focusing on examples from catastrophe insurance, public water management, and coastal wetland protection, I look at how efforts to incorporate information about the physical costs and consequences of climate change into the delivery of goods and services in these domains trigger political struggles about how these costs will be distributed.

Much of the sociological literature on climate change has sought to understand why, despite overwhelming consensus among scientists about the anthropogenic sources of climate change (Oreskes 2004; Cook et al 2016), institutional efforts to reduce greenhouse gas emissions have been spectacularly unsuccessful at doing so (Skocpol 2013). Scholars have repeatedly shown that policies attempting to reign in the production and consumption of fossil fuels, the main source of these emissions, has created intense opposition by economic and political incumbents whose activities are threatened by such policies (Perrow and Pulver, 2015; Jacques et al 2008). This has led to an organized effort by these incumbents to "institutionalize delay" of any meaningful emission reductions (Brulle 2014). Such tactics have included manufacturing uncertainty about the scientific evidence of climate change (Dunlap and Brulle 2015), the spread of misinformation through media and policy networks (Boussalis and Coan 2016; Farrell 2016), and attempts to discredit and shame individual climate scientists (Goldenberg 2012; Lahsen 2013).[1]

While much has been learned from these studies about deliberate efforts to create social inertia around climate action (Brulle and Norgaard 2019), they do not provide much insight into social and political dynamics that occur when organizations, political actors, and communities take the forecasts of climate change seriously. In this dissertation, I turn the analytical gaze away from the familiar "merchants of doubt" (Oreskes and Conway 2010) to focus on actors who consider the future changes anticipated by climate models as major threats to individual and organizational projects. Exposed to data from climate models, these actors see an unavoidable need to shift their behavior and prepare to meet the unfolding reality of climate change, particularly in the form of increasing extreme weather, natural resources scarcity, and deteriorating environmental conditions. In other words, rather than inquiring about "delay", this dissertation seeks to understand how scientific knowledge about climate risks is made "actionable".

Another way scholars have made sense of these divergent social responses to climate change (i.e.

[1] A major target of the actors in this "climate change counter-movement" have been to undermine the credibility in the global circulation models (GCMs) that provide much of the insights into future climate impacts (Lahsen 2008; Edwards 2010). Raising even marginal levels of doubt on the validity of GCMs has, as numerous scholars continue to research, revealed surprisingly fragile relationships between trust, credibility, and expertise within liberal democracies (Eyal 2019; Oppenheimer et al 2019).

delay and actionability) has been to distinguish between problems of climate mitigation and problems of climate adaptation. Mitigation implies simultaneously deploying new technologies that do not produce greenhouse gas emissions and putting a stop to older forms of energy production and industrial manufacture that still rely on fossil fuels. Achieving mitigation requires creating new rules of compliance and enforcement that dissuade or punish previously lucrative forms of economic activity. Because of the deeply entrenched nature of fossil fuels within modern life, the economic interests connected to these activities have been largely successful in postponing and weaking national and international rulemaking processes that would constrain the use of fossil fuels (at least to the extent and rapidity that scientists consider necessary for avoiding true catastrophic changes in the future (IPCC 2018)).

The second primary social response to climate change, what scholars call adaptation, is conditioned in part by the results of inaction around mitigation. Adaptation typically refers to a broad set of strategies, measures, and techniques that aim to make social and ecological systems more robust and resistant in the face of human-induced climate change (Moser and Boykoff, 2013; Rodin, 2014; Anguelovski et al 2014; Füssel 2007). The less mitigation is done, the more adaptation will be needed. Also, because engaging in adaptation depend less on constraining the activities of powerful actors, it is not subject to the same institutionalization of delay that scholars observe in the realm of climate mitigation. Social science research into adaptation, as a result, is much more heterogenous than research on mitigation and includes analyses of the ability of human, technical and ecological systems to withstand and rebound from particular climatic conditions (Davoudi et al 2013), evaluations of criteria for improving the design of built environments (Bulkeley and Betsill, 2013), consideration of the effects of climate change on global inequalities (Ciplet et al, 2015), and studies focusing on how adaptation outcomes are shaped by competing perceptions of local climate risks and protection needs (Sovacool et al 2015).

Through this dissertation, I aim to contribute to the growing body of sociological research on this latter topic in particular: the politicization of climate adaptation. I do this by analyzing the processes by which knowledge about specific dimensions of climate change (i.e. changes to temperatures, precipitation, sea-level rise, and shifts in subcomponents of the climate system, such as the Atlantic Multidecadal Oscillation) are rendered "actionable" for economic and administrative actors. Actionability, I argue, is about taking the results of climate science seriously and translating knowledge of climate risks into practices that preserve, maintain, or positively transform organizations' abilities to provide existing goods and services in a climate-altered future. Across my three cases, however, I follow how efforts to institutionalize information about climate risks into existing mechanisms of economic or policy-oriented decision-making also provoke political struggles over the distribution of the negative effects of climate change.

Theoretical Approaches

Each case of this dissertation points to actionability as a complex and ongoing process of translation between the scientists that have been studying future climate change and individuals concerned with how those future impacts will affect their work. By focusing on key knowledge brokering organizations and actors within each of my cases (catastrophe modelers; irrigation dependent farmers; coastal zone planners), I hope to bridge different theoretical approaches to understanding how institutional change occurs, bringing in particular a consideration of micro-processual interactions together with an analysis of field-level dynamics. Within science studies scholarship, Actor Network Theory (ANT) provides a template for how to trace the ground-up construction of a social category, such as "actionability", via processes of enrolment, trials of strength, and the stabilization of agreement through material interventions that help structure interactions and facilitate institutionalization across networks (Latour, 2007; Callon 2007). Studies conducted in the spirit of ANT frequently emphasize the importance of reflexivity as a critical element and strength in the production of knowledge. And while a good portion of this scholarship focuses on a specific type of reflection – technoscientific – and on a specific type of reflective actor – scientists (Collins, 1975; Latour and Woolgar, 1979; Callon, 1986; Latour, 1988, 1995; Pickering, 1992) – the cases in this dissertation focus on a wider range of reflexive practices and a wider range of reflexive observers, including public administrators and farmers, actuaries and regulators, hydrology engineers, indigenous tribes, and oil lobbyists.

Besides foregrounding the social construction of actionability, this dissertation also seeks to answer a central puzzle about institutional innovation – how do organization's make decisions in the face of operational uncertainty (Simon, 1947; March and Simon, 1958; Cyert and March, 1963)? In other words, given persistent uncertainties about the exact scope and scale of climate impacts, what factors lead organizations to view climate change as an organizational problem worthy of immediate attention (excluding attentions geared toward denying or rejecting the problem, such as "institutionalized delay")? Subsequently, how do organizational understandings and framings of climate risk help legitimate and constrain responses to the problem? Existing research on institutional dynamics suggest that shifts in regulatory regimes, crisis in production or service delivery, competition with rivals and social movement pressures can all precipitate change within organizations (Morrill et al, 2003; Fligstein 1996); what is not well understand is how organizations become compelled to act on the basis of scientific projections, especially when such action is counter to an organization's short-term interests. One explanation suggests that certain individuals, what Paul DiMaggio calls "institutional entrepreneurs" (1988) play an outsized role in shaping institutional change. These individuals are more skilled at producing desired outcomes in organizational settings than others, and understanding why scientific forecasts of climate change become organizationally meaningful likely means paying attention to the work being done by these individuals.

Additionally, while theories of organizational behaviour help frame some of these questions regarding institutional change, they tend to do so from the perspective of a single firm or organization; they do not necessarily help us grasp organizational responses to uncertainties that operate at the level of what institutional theorists call the organizational-field or strategic action field (DiMaggio & Powell 1983; Fligstein & McAdam, 2015). Borrowing from Bourdieu (1985; Bourdieu and Wacquant, 1992), Fligstein and McAdam define strategic action fields as "socially constructed arenas within which actors with varying resource endowments vie for advantage" in the pursuit of competing goals and outcomes (2011, p3). "The boundaries of strategic action fields", they emphasize, "are not fixed, but shift depending on the definition of the situation and issue at stake" (Ibid. 4). Bringing the idea of the field into our analysis offers opportunities to combine in fruitful ways sociological theories of practice with organizational concepts of decision-making. How do uncertainties operate at the boundaries and interstices between different field-level actors? Furthermore, by bringing attention to the nitty-gritty work being done by specific organizational actors interested in translating science into action (Latour 1987), the analytical approach of this dissertation also creates potential bridges between social studies of science, actor-oriented organizational scholars (Lawrence et al 2011; Lounsbury 2008) and structural notions of institutional action. Rephrasing the old organizational studies puzzle posed above, this project aims to analyze how organizational actors negotiate decision making in the face of field-level uncertainty and how including new information in decisions leads to field-level "uncertainty spillovers" that spur subsequent rounds of institutional adjustment (including retrenchment).

In summary, this research agenda combines concepts and methods from the fields of sociology of science, organizational studies and economic sociology to make sense of the transformation of climate science and its uncertainties into "actionable information" for the purposes of private and public governance. It focuses on substantive issues of value, equity and climate change, examining how existing market, and market-oriented, actors are trying to convert knowledge about climate impacts into financially relevant information – both in private sector and public administrative settings. Where does the motivation – or resistance – for this kind of conversion come? How do past solutions to problems of resource management or risk assessment create path-dependencies for new approaches that take climate change into consideration? Are their deeper types of integrative work that involve institutional transformation greater then just adding an additional input into the ready-made machinery of existing organizational decision-making? To answer these questions, I look specifically at the tools, interfaces and experts assisting in this process of making knowledge about climate change "meaningful" for different institutional practices (Callison, 2014).

Framing the Argument

While composed as standalone papers, the chapters of this dissertation all share some analytical and schematic similarities. My three field-level cases include markets in homeowner disaster insurance, regional resource management, and coastal protection investments. The cases are expanded on in detail below, but in brief overview:

- *Homeowner Insurance*: private catastrophe modeling firms help (re)insurance companies, regulators and rating agencies anticipate potential losses from natural disasters in specific locations. Model outputs serve as a means of reaching agreement about what the appropriate price should be for underwriting residential property risks, reinforcing broader economic stability in important local sectors such as the housing market. The changing nature of extreme weather events – in particular hurricanes – have prompted efforts by these firms to bring climate data into actuarial practices, efforts which have triggered resistance and reorganization within the broader (re)insurance field.

- *Water Management:* public water agencies are charged with anticipating fluctuations in resource availability on a daily basis, as well as making long-range decisions about public infrastructure investments to support water allocation commitments. They also find themselves as arbiters of competing stakeholder and user groups, each with different organizational needs and cultural attitudes toward water. Employees of a French water agency conducted a public campaign that introduced downscaled projections of climatically induced changes to local water availability to local stakeholders over the course of three years. The campaign, created to facilitate discussion and decision making, ended up calling into question both the existing allocation system as well as threatening the underlying management rationale based on maintaining the integrity of ecological systems.

- *Coastal protection*: preventing widespread harm from large-scale natural disasters is a task for which government is usually held responsible. In the case of coastal zone management, this means investing public monies in infrastructure such as seawalls, levees, and storm barriers to protect communities against flooding. As anthropogenic conditions of coastal zones change in the state of Louisiana accelerate, the scale of territory at risk is quickly exceeding the State's protective capacities. In developing criteria to determine what deserves saving and what does not, existing political economic relations severely constrain the types of actionable measures that state officials are able to support, with large adaptation expenditures going toward defending economic activities, such as the oil and gas sector, that generate significant tax revenues for the state, despite the fact that these industries are driving local vulnerability.

Within each case, I characterize how key actors currently make decisions regarding the delivery of organizational goods or services. I examine how these existing routines and procedures for decision-making emerged as solutions to past social disputes around 1) how to price homeowner insurance, 2) how to allocate access to water under moments of environmental stress, and 3) how to determine which coastlines get protected and which do not. These considerations set the stage, so to speak, for a historical understanding of the system of expectations that frame how actors pursue individual or organizational objectives in each of my cases prior to the problem of climate change.

Then I consider the institutional conditions that prompt concern about climate change and compel a core group of actors within each of these fields to seek better information about the scope, scale, and timing of climate impacts on their domain of expertise or operation. Concerns about climate change emerge, I argue, because climate knowledge (in the form of forecasts and projections) produces operational "dissonance" for these actors. In other words, knowledge about future impacts creates a realization for these actors that climate change will likely jeopardize their ability to continue performing their current administrative or economic functions.

Finally, I trace deliberate efforts of actors in each of my cases to overcome this dissonance by making knowledge about climate change "actionable" through existing mechanisms and tools of administrative and economic decision-making. I consider these efforts a type of "institutional work" (Lawrence et al 2011), undertaken by specific individuals within their respective organizations, and targeting the reduction of uncertainty in future outcomes of organizational action. The results of this institutional work, however, generates broader, field-level disruptions. Efforts to adjust one element of decision-making (i.e. how hurricanes are simulated or how river flowrates are measured) affects the expectations of other field-level participants creating political struggles over what and for whom the future is being made actionable.

Decision-making devices and institutional stability

At the heart of each of my cases is a complex set of tools or devices that structure how actors in each institutional setting arrive at decisions legitimately. I approach these tools and devices of from a sociologically contingent and historical perspective. These kinds of socio-material apparatuses (risk assessments, allocation systems, and infrastructure investment criteria) succeed not simply because they reduce some objective measure of uncertainty but because they organize expectations within an organizational field. They depend to a certain extent on a social agreement about how specific tools and devices can be judged and held accountable (and about the kind of data that they can include in their calculations). Such agreements are often obtained through conflict and compromise, and by striking the right balance between procedural transparency and technical standardization.

A classic example of the kind of apparatus I am describing is the development of cost-benefit-analysis by the Army Corps of Engineers to justify the merit of their large-scale infrastructure projects to Congressional appropriators. As Porter (1995) describes in his history of how quantification became a crucial means for securing the trust of the governed, the Army Corps sought a mechanism that could perform two tasks: help reduce the arbitrary and uncertain nature of their building assignments; and position them favourably in the battle for scarce public resource against their administrative rivals, the Bureau of Land Reclamation. Engineers within the Army Corps proposed cost-benefit-analysis as an impersonal, simplified way of assessing the value of a project that made construction goals commensurate with budgeting logics of legislators. And as a procedure, cost-benefit-analysis was easily integrated into the process of evaluating any and all potential government projects. The technique became systematized – it is still hard to make a decision about federal appropriations and budgeting without first passing through a cost-benefit analysis, or CBA, of the decision.

Overtime, the institutionalization of CBA within different branches of the government created a level of certainty about the process and criteria upon which expenditure decisions are made. This advanced the adoption of CBA by organizations or firms doing business with the United States, turning CBA into an indisputable decision-making device and advancing a degree of stability about how such decisions are made, thus reducing field-level uncertainty. There are countless other examples of such decision-making devices, from financial models used in modern portfolio management (MacKenzie, 2006; Polillo, 2015), to utility pricing schemes (Granovetter and McGuire, 1998; Breslau 2013), to oil production formulas (Shafiee, 2012), to collection protocols for natural history museums (Star and Greismeier, 1989), to public-school teacher evaluations (Griffen and Panofsky 2021), to admission rubrics for law school (Espeland and Mitchell, 2016). The overall point is that in each of my cases, I set the stage with regards to existing frameworks for how legitimate decisions are achieved, and show how these frameworks are built on accommodation, negotiation and compromise among the set of organizations and actors who abide by the framework. Decision-making frameworks and devices are my short hand for describing what encodes social agreement around some process-oriented outcome.

Suffice it to say, when a new problem emerges within the context of an organizational field, not all actors within the field view the problem in the same context nor are affected by it in the same manner. But once one set of actors work to make the problem into an issue, their efforts can have spillover effects for other field-level actors depending on the scale and scope of the problem.[2] Establishing a problem as a field-level matter depends on a number of factors, including the insolubility of the problem, the interconnectedness of the problem (i.e. the number of other decisions and expectations the problem impacts), but also the persuasiveness and institutional work of “institutional entrepreneurs” (DiMaggio 1988) who labor to turn the issue into what scholars in the social studies of science have called a “matter of concern” (Latour 2004a; Callon, 2007; Epstein, 1995; Wynne, 1992). The contradictory, complex, and interdependent relationship of climate change to multiple forms of human activity is well documented (cf climate change as a “super-wicked problem”; Levin et al, 2012). The efforts of actors working to turn climate change into a social problem, however, is fragmented and spread across many different domains.[3] One of the goals of this dissertation is to demonstrate the breadth of these domains, particularly with regards to concerns about climate impacts. Another is to argue that climate change, as a phenomenon, is interacting not just with the natural and built environments, but also with the institutional environments of these decision-making devices and the social contracts they encode. Part of the “institutional work” of actors concerned about climate change, as each case subsequently explores, is to navigate and manage spillovers that come from trying to

[2] In thinking of other social problems that have had transversal, field-level impact on organizations, we might consider the changes that the civil rights and women’s movement wrought on workplace diversity and inclusion mandates (cf Dobbin and Sutton 1998). We may also want to consider how initial changes, while seemingly impactful, appear to have succumbed to forms of organizational myth and ceremony that stymie more meaningful changes to corporate work-life (Dobbin and Kalev 2021).

[3] This is truer for climate adaptation than climate mitigation. Mitigation to climate change is relatively straightforward in the sense that governments have largely identified the principal sources of anthropogenic greenhouse gas emissions and measure these sources on a regular basis (both onsite measuring instruments and satellite measurements). Tackling adaptation, however, requires assessing social and environmental vulnerabilities that depend on multiple, difficult to measure factors which largely manifest themselves at the local level. While the geographic scope of climate impacts may be revealed at coarse-resolution via global circulation models, producing information about adaptation needs at more fine-grained scales depends on much more localized form of analyses. It deserves mentioning, with regards to mitigation, that while emissions from energy are relatively easy to account for, replacing hydrocarbons as a feedstock for fertilizer, chemical processing, plastics production, and aluminum and cement manufacturing is much harder, as is managing emissions from various forms of land-use.

translate information about climate impacts into sets of organizational actions.

Adjusting to dissonance

What prompts organizations and actors to be concerned about climate change and seek better information about it? At a general level, I argue, because they encounter some degree of what John Dewey (1910) called "perplexing situations" and economic sociologists David Stark and Daniel Beunza (2009) have reframed as "dissonance". These are instances of friction and uncertainty when previous modes of action linked to particular outcomes no longer obtain the same results. Perplexity and dissonance are natural features of social and organizational life, but, according to Dewey, they are not very well tolerated and are something that humans seek to reduce as best they can. Among different available remedies, actors can change current actions to try and obtain the same results as pertained in the past, or actors can realign expectations to accommodate changes in opportunity structures and circumstances for action (cf Dewey, 1910; 101-115). In other words, dissonance produces a rupture in what actors anticipate, which initiates a social process of reflection, reinterpretation and readjustment of the link between the means and ends of action. What are the sources of knowledge that trigger dissonance regarding climate change? [4]

Much has been written about the intertwined history of climate science and the emergence of

[4] This process also evokes theories from organizational behavior about how uncertainty over outcomes drives organizations to "seek" for means-ends solutions. Since preferences are not pre-specified but rather discovered through this "search" processes, the ultimate solution selected leads to a satisficing, rather than optimizing, outcome (Simon 1956; Brown 2004). Preferences and performance criteria, in other words, are dynamically changing (Gavetti et al, 2008). One major difference between the analysis in this dissertation and those typically undertaken by Carnegie School style scholars is that, while each of my cases opens with the problem of climate impacts as framed by particular organizational actors, I follow the dynamics of dissonance and translation beyond these initiating groups. This helps me situate the struggles regarding the actionability of climate knowledge as they move between heterogeneous organizations at the level of the field (Schneiberg, 2002; Schnieberg and Soule, 2005)..

climate change as a topic of public policy (Weart 2003; Hulme 2009; Edwards 2010; Howe 2014; Sörlin and Lane 2018). A brief recounting of this history might start in the U.S. with the National Research Council's publication of the Charney Report in 1979, which assembled a body of relatively new science showing evidence that human emissions of greenhouse gases were altering the planet's atmosphere. Produced by the leading experts in meteorology, computer simulation, oceanography and atmospheric sciences, the Charney Report laid out the scope of the problem in terms that have hardly changed since its publication: the burning of fossil fuels was changing the radiative balance of the earth; under best estimates, a doubling of carbon dioxide in the atmosphere – the main greenhouse gas – would result in a change in global mean surface temperature between 1.5-4.5 degrees Celsius (cf IPCC 2021 p130).[5] Such a change would result in potentially catastrophic changes to ecosystems and human systems. The Charney Report garnered significant interest from policy makers, journalists, administrators, environmental advocates and members of industry (Rich, 2018). Momentum within the scientific community and amongst policy makers led to a series of international meetings that culminated in the creation of the Intergovernmental Panel on Climate Change (IPCC) in 1988 (Franz 1997; Agrawala, 1998a, 1998b) and eventually led to the United Nations Framework Convention on Climate Change, negotiated in 1992 at the Rio Summit.

The IPCC was tasked with assessing the global climate science literature and issuing reports to the member states of the United Nations (UN), beginning with its First Assessment Report in 1990. These reports laid out all that was known about the sensitivity of the earth's radiative

[5] The latest IPCC report published just weeks before this dissertation was finished (AR6 WGI volume on the physical basis of climate change), tightens this sensitivity range for the first time to 2.5-4 degrees Celsius. A refinement, more than a revision, indicating the stability of these earlier estimates and scientists' underlying understanding and ability to model the problem.

balance, and over subsequent iterations, more and more details about how the greenhouse effect would lead to a hotter planet, rising seas, acidifying oceans, increasingly extreme weather and large-scale ecological disruption. Because of the nature of the models that generated these conclusions, however, most of this knowledge was aggregated in the form of global averages that were difficult to associate with specific localities (Edwards 2010). Thus, while certainties began to take shape about broad trend lines of climate change, uncertainties about medium-term changes in specific places were initially out-of-reach of the early simulation techniques (Miller and Edwards 2001). Even though early versions of the IPCC attempted to communicate impacts at both sectoral and geographic levels, the quality of information available within these contexts was frequently tentative, fragmentary, and bounded by high margins of error (Dessai and Hulme 2004).

The "globalizing" of the climate problem, which occurred during the 1980s and 1990s, was consistent with other institutional arenas of environmental policy, and trained policy maker attention toward mechanisms of international deliberation that deemphasized other forums for shaping political expectation (Meyer et al, 1997). But as many analysts have pointed out the international political forums created to address climate change, such as the UNFCCC, have not performed as they were designed to do (Aykut and Dahan 2015). Policy was elusive because commitments for emission reductions were pegged to global figures that actually ended up diluting every party's sense of responsibility. As already mentioned, a great deal of evidence points to how expectations about future risks were also muddied through deliberate campaigns of disinformation, innuendo and attacks against the credibility of climate scientists by those industries and countries who most benefited from the fossil fuel economy (Farrell 2016; Brulle

2014; Supran & Oreskes 2017). But there is also a case to be made that the risks to be avoided, as framed by the models, were either so grandiose and sweeping or so diffuse and pervasive as to obstruct and disarm meaningful "sense-making" efforts by the very individuals or organizations who might take action (Weick, 1988, 1995).

At the national level in the U.S., for instance, efforts to politically resolve the threat posed by climate change have foundered because the distribution of advantages and disadvantages produced by specific policies were framed at the level of economic sectors and thus made it difficult to generate support of citizens who had a difficult time identifying how potential policies might affect their daily lives (Skocpol, 2013). Such policy interventions were, in fact, easy for opponents to cast as individually harmful: Pricing carbon, according to the campaign slogan, would kill jobs and increase energy costs for working class Americans.[6] Because the bands of uncertainty around what emission reductions today would prevent in terms of climate consequences tomorrow, conditions of success were hard to narrativize or turn into expectations that could reward politicians or companies for taking bold action (Rich 2018).

In assessing how dissonance prompts disruption and changes in expectations, particularly regarding exposure to risk, we need to address where expectations come from and how they become coupled and uncoupled to different regimes of action and sense-making.[7] Sociological

[6] This rhetoric is rampant within the Republican Party of the United States. Just picking from the headlines around the filing time of this dissertation, Republican Senator Rick Scott of Florida, is quoted in a New York Times article: "I'm not doing anything to raise the cost of living for American families". And while the Senator concedes that something needs to be done about climate change, "you can't do it where you're killing jobs." (Friedman and Davenport 2021)

[7] The strength of coupling between expectation, action and outcomes varies in different situations, but in the case of expectations about risk there needs to be some general coordinates of causality that can assign specific actions as being responsible for the avoidance of specific risks (Ewald 2020).

interest in expectations can be linked at least back to Durkheim, who viewed future-oriented thinking as a unique quality of humans that was tied to norms and social structure. Channeling Durkheim, Mary Douglas argued that "institutions encode expectations" (1986, 48). Social expectations have a cultural and enduring character, which account for their resistance to change (despite new types of scientific information). Expectations, in other words, are not instrumental expressions of rational preference, but dynamic, contingent, and emergent; open to revaluation. In his study of how economic life is suffused by imagined futures, Jens Beckert identifies what he calls seven social influences on expectations:

> *1) Opportunity structures (the American Dream); 2) Cultural frames (expectations picked up by ones shared position in a social class or ethnic group – habitus); 3) Institutions (legal institutions like the contract strongly shape economic expectations); 4) Networks (social relations play a role in diffusion of perceptions of the future); 5) Cognitive devices (i.e. economic theories; forecasting tools; stochastic models); 6) Mass media (disseminates scripts for possible lives); 7) Past experiences.* (Beckert, 2016; 90)

What is compelling about Beckert's typology of the social dimensions of expectations, is that it provides an analytical grid for understanding the interaction of dissonance and future oriented actions. It shows how obstruction and innovation toward the inclusion of new information within action frames can coexist across different dimensions of social life, as dissonance disrupts certain sources of expectations and not others. As such, Beckert's typology of expectations offers a way to think through and connect the different cases in this dissertation.

In the decades that have elapsed since the first headline grabbing reports about climate change, climate scientists have begun to refine projections about the localized consequences of anthropogenic warming of the planet with more and more certainty. A new field of attribution and detection studies has substantiated the argument that humans have already begun to alter current weather and climatological events (Allen, 2003; Stott et al, 2004; NAS, 2016; Betts 2021). The "signal" has leapt from the pages of scientific articles, instrument readouts and computer calculations and is making itself felt in tangible ways in the form of more frequent heat waves, more intense storms, longer droughts, faster spring snowmelts, amplification of fire seasons, explosion of pest populations, shorter intervals between major coral reef bleaching events, shrinking glaciers and sustained coastal erosion and flooding from rising sea levels. To the extent that risks from future change are seen largely as inevitable now, much attention has turned to understanding the parameters of change and what can be done socially and ecologically to improve adaptation and resilience to climate changes.

As the science has gotten sharper the scientific community has enhanced its attention to estimating and understanding the impacts of climate change in specific places. A major trend is to re-territorialize the climate and understand the idiosyncrasies of how anthropogenic forcing of the global system manifests itself locally. And while large scale scientific summaries such as the IPCC continue to be establish a baseline of globally recognized, peer-reviewed knowledge about climate change, jurisdictions at the national, subnational and local levels are increasingly conducting their own assessments to understand how climate impacts will effect urban and regional infrastructure, labor market dynamics, utility service delivery, public health and safety among many other concerns.[8] Given how the governance of climate impacts will inevitably fall to more territorial and sectoral scales of decision making, and not the kind of global deals that characterized the early international politics of emissions reductions, there have been increasing calls from local officials, technical administrators, risk managers and others for "actionable" information about climate change that can help them communicate and justify to citizens and customers the need to modify certain aspects of goods and service delivery in order to maintain as much as possible existing economic and social relations. Not only is "actionable" information invoked as a means for shaping these expectations, but it is also requested as a way to perform "counterfactual display" (Ehrenstein & Muniesa, 2013), to show how conditions would have been worse in the absence of the decisions taken. This ability to entertain and sharpen the contours of counterfactual futures is one feature among many of "actionable" information, to which we now turn.[9]

Making Science "Actionable"

What does it mean to make science "actionable" in the context of climate change? What exactly is being made "actionable"? Actionability, I argue, is about articulating knowledge and data produced by climate scientists with the risk evaluation and risk management needs of a wide range of administrative and economic systems of operation and decision making. This includes

[8] Within the U.S., the trend can be tracked in decreasing order of jurisdictional scale from the national to the state to the urban territory with the creation and release of the first National Climate Assessment in 2000 by the U.S. Global Change Research Program (the second NCA followed in 2009, the third in 2014 and the fourth was released in 2017); the creation and release of the first state-level climate assessment by the California Natural Resources Agency in 2006 (the fourth California Climate Change Assessment was released in 2018); and the creation of a suite of city-level assessments beginning with New York City's PlaNYC in 2007 and Chicago's Climate Action Plan adopted in 2008.

[9] Along these lines, and connecting the importance of "counterfactuality" to expectations, Beckert proposes that "Concepts of risk share similar historical roots with that of the open future, for risk emerges when courses of action are decided upon using projections of a 'counterfactual' future, which may turn out differently than predicted and when any resulting damage is attributable to these decisions. (Beckert 2016, 31)

everything from decisions about where to invest money in public infrastructure to whether to renew insurance contracts to which crops farmers should plant in the future. More than a buzzword, actionability describes an intervention-oriented relationship to climate knowledge, a process for harnessing science toward specific strategic purposes that is recursive and pattern-seeking, rather than linear or reductive (cf Sobel 2021 on "usable science"). It often involves converting output variables that emerge from the global climate models, for instance, into input variables for other, more physically and geographically-restrained modeling environments – frequently through a process called downscaling[10] – that can identify short- to medium-term climate impacts for specific socio-material systems (i.e. river basins, built environments, electricity grids, commodity supply chains, etc). The next stage of actionability involves embedding this information across many simultaneous organizational contexts and systems – within what I call *climate-enhanced decision devices* – that directly influence the governance and delivery of economic or administrative goods and services.

Making information "actionable" is neither evident nor anodyne. It requires extensive "institutional work" by those actors trying to affect change to convince differently positioned actors within a strategic action field (i.e. catastrophe insurance, public water management, or coastal protection) that any reconfigurations resulting from the consideration of climate change will not disrupt the specific interests of particular actors disproportionately more than others. Despite the best efforts of these "entrepreneurs of actionability", however, this process of adjusting the production or delivery of goods and services based on knowledge about climate

[10] Other techniques of information processing may also be employed to make climate science "actionable", such as machine learning, expert elicitation, or agent based-modeling (and these techniques may be combined, as well), but downscaling is by far the predominant technique at the moment.

impacts frequently creates uneven outcomes and thus opens up political struggles over how the future should be prepared for and anticipated.

The notion of "actionable science" or "actionable information" extends far beyond the domain of climate change. It is an emic category used by a wide range of professionals in the fields of risk and crisis management, policing and surveillance, health care delivery, education policy, military and business intelligence, data processing and network security – all organizational fields that face large degrees of uncertainty in coupling desired organizational outcomes with decisive, distillable inputs. While the definition of the term "actionable" is fluid and evolving within each field, there is nonetheless a shared spectrum of meaning. [11] On the broad end of the spectrum, global public health expert Leslie Gerwin writes by, "By actionable information, I mean accurate facts and reasonable interpretations of those facts upon which an individual should rely in making reason-based decisions." Discussing the context of decision-making within a pandemic, she says "this includes information that allows an individual to weigh the risk to one's self, family, and community before deciding to act in an uncertain environment under threatening conditions" (Gerwin, 2012, 630).

The making of "actionable information", following Gerwin, is the transformation of a fact into a timely interpretation of what needs to be done in a situation of uncertainty to secure core life goals – it is the result of a sequenced set of steps linking the production of a fact with the taking

[11] "Actionable" has two formal definitions. According to the Oxford English Dictionary, the first and older usage (dating to the early 1600s) refers to an event that "gives cause for legal action". The alternative definition emerged in the early 1900s and means something that is "able to be acted upon, or put into practice; useful; practical". It is the relation of "information" to this latter definition that is invoked in this introductory chapter, although there are interesting tensions between the two definitions. In the conclusion to the dissertation, I consider how legal actionability and practice-oriented actionability relate to each other in the context of climate impacts.

of a decision.[12] It is also information that, in the first instance, assists individuals in making choices to mitigate risk, and make an otherwise threatening situation less so. The European Union Agency for Network and Security Information (ENISA), for instance, has a "good practices" guide on "Actionable Information for Security Incident Response" in which it situates a definition of actionability within a wider genealogy of usage:

> *In business and management, the term 'actionable information' is often used to describe market data, reporting on trends and other information that can be used to make specific, strategically sound business decisions. To meet the definition of 'actionable' to a business executive it must be relevant, timely, accurate, complete with respect to some set of business goals, and ingestible. The same concept can be applied to IT security, where actionable information is used to take actions that mitigate against future threats, or help address existing compromises.* (ENISA, 2014, 2)

By combing different sources, it is possible to identify properties of "actionability" that we might consider commensurate across a variety of uses. Actionable information is information whose value comes from: its strategic relevance to a decision currently at hand; its dynamic and timely arrival within the overall flow of the decision-making process (neither too early nor too late); its accuracy in terms of being able to point toward a space, moment, or scale of action that will produce a desired outcome; its ability to detect meaningful patterns in a surfeit of data (i.e. to "cut through the noise"); a capacity to constantly update itself based on changing conditions of

[12] John Dewey describes the function of "foresight" in a similar vein: "Foresight serves to ascertain the meaning of present activities and to secure, as far as possible, a present activity with a unified meaning" (Dewey, 1922; 25). The process of developing and articulating a "unified meaning", and linking it to "present actions", could be another way of describing the social construction of "actionability".

the world; and finally, its 'ingestibility', or arrival "in a form that allows the straightforward import of the data into an organization's information management system" through consistent "formats and transfer protocols used for data sharing" (Ibid., 4). Borrowing a metaphor that hangs ambiguously between biology and the culinary arts, 'ingestibility' implies a kind of preparation of information, through coding and formatting, so that it corresponds to both the "appetite" and "metabolism" of a given organization's existing systems of information processing.

"Actionability" as a term has also become an object of sociological analysis, particularly in the field of genomic sequencing, where it is being increasingly used to describe how results obtained from sequencing an individual's genome can serve as a means for guiding decisions about medical treatment. Summarizing public-oriented genomic research as well as brochures and marketing materials by private companies about patented sequencing technologies, one group of sociologists writes that "genomic results are made 'actionable' by articulating them with existing clinical routines, clinical trials, regulatory regimes and health care systems" (Nelson et al 2013, 407). Other scholars have gone further in arguing that this act of articulation is achieved not just through the collection, coding and formatting of information, but also through human interaction. Information about the importance of an individual's genetic makeup, for instance, is made meaningful (i.e. "actionable") to patients of neo-natal care clinicians who situate the information within existing norms and procedures for how patients typically weigh decisions about whether to bring a pregnancy to term or not (Stivers & Timmermans, 2017). These are useful and promising examples of how actionability is pursued through the work of institutional translation at the very micro-level.

In relation to climate change, a programmatic call for "actionable information" is detectable at least beginning in the early 2000s.[13] An article in 2006 by a group of earth systems scientists makes the case in the *Proceedings of the National Academy of Science* for the creation of a national climate service, analogous to the National Weather Service. "Climate science has made major advances during the last two decades, yet climate information is neither routinely useful nor used in planning," they argue. "What is needed is a sustained mechanisms for promoting science to support decision-relevant questions, translating new climate information into relevant decision environments" (Miles et al, 2006, 19616). In 2010, the U.S. federal government followed through and created the National Climate Service, housed in the National Oceanic and Atmospheric Administration (NOAA). Their mission was to try and territorialize data from the global climate models and combine it with other sources of science. "Models are critical," the service's first chair, Thomas Karl said in interview shortly after taking command, "but there are important pieces often left out of the models; land use changes, ocean circulation, sea ice, biogeochemistry, land ecology…we're trying to make climate models more physically realistic. But no matter how good the models get, we have to understand the uncertainties coming from the models and tailor that information to the regional level." (Kerr, 2010, 29). In 2011, however,

[13] In tracing the connections of actionability to climate science, I think it's important to consider that the category of "actionable information" has certainly existed in different guises in the past and shares at least a passing resemblance to notions of "instrumental", "applied" or "useful" science or knowledge (Lindblom and Cohen 1979; Stokes 1997; Dear 2006; Clark et al 2011). In a critical appraisal of these different idioms, Deborah Coen offers a genealogy of what she calls "usable" climate science: "To be usable means to ensure that research will serve the needs of those impacted by climate change." As she goes on to write, "Perhaps more than any other policy problem, climate change has resisted this move, in part, because the global models that capture its planetary-scale effects have not had the capacity to predict impacts at politically actionable scales" (Coen 2021, p1). Usable and actionable reflect perhaps a choice of where to focus one's analysis. Whereas Coen emphasizes more the upstream stage of scientific production, actionability I would argue is more downstream – although both involve some form of iterative feedbacks between scientific research and decision makers (at least in an ideal scenario). Actionability, as seen by its uses in other fields, is very much informed by ideas of threat-avoidance, disaster-preparedness, and time-constrained decision-making, while Coen's concept of "usable science" captures a category of research design defined less by situations of urgency and data noise.

Congressional Republicans killed the service, refusing to provide the budget for an explicitly climate-oriented branch of NOAA.[14]

In the same year the U.S. climate service received the axe, the World Meteorological Organization (parent organization of the IPCC) issued its global framework for climate services aimed at providing information to developing countries about climate change (WMO 2011), and actionability was a central theme of a World Climate Research Program's (WCRP) conference, "Climate Research in Service to Society", that coincided with the creation of the WMO's framework. As the Director for the WCRP and lead conference organizer, earth systems scientist Ghassem Asrar, stated in a recap of the conference, "Decision makers – including water providers, farmers, insurance companies, oil exploration companies, and many more – need climate and other scientific information to guide decisions." But "there is often a mismatch between the scientific data available and the information needed. There is a need for 'symbiotic' relationships between providers and users of climate information to ensure that *actionable (timely, accessible, and easy to understand) climate information* is developed and used effectively" (Asrar et al, 2013, 9; e*mphasis my own*).

This mismatch between data and information – what we might call the "actionability" gap – is evoked over and over again in each of these contexts: "We're drowning in data," a WCRP conference attendee told a reporter for *Science Magazine*, "and we're not very good at turning it

[14] "Our hesitation", Representative Andy Harris, a Republican from Maryland told NOAA Administrator Jane Lubchenco at a hearing in June of 2011, "is that the climate services could become little propaganda sources instead of a science source" (Vastag, 2011). This reaction actually points back to the strategies of "institutionalizing delay" by casting doubt on climate science (which the Republican official in this quote calls "little propaganda sources"). In this case, the emphasis is on preventing the science from being conducted or assembled in the first place, but its important to point out that processes of delay and actionability can be in interaction.

into information" (Kerr, 2011, 1052). On this point, some commentators see opportunity for enterprising individuals and organizations. As one of the panellists at the WCRP's conference puts it: "'There is a business case to be made here. On the one side are the people who create and 'own' the data, who may be government scientists, and on the other side are users. In between there's the chance for private companies to take the data and use it to deliver more detailed, relevant information to decision makers who need it." (Asrar et al 2013, 10). In the absence of a government consolidation of climate services, in other words, actionability is also a value proposition for those who can manage the uncertainties in the science and translate that into sellable information.[15]

An alternative, non-market driven logic to creating actionable information is evoked by the STS idiom of "co-production" between scientists and potential users (Jasanoff, 2004). The authors of "A How-to Guide for Coproduction of Actionable Science", published by a forestry management expert, public lands specialist, climate adaptation professional and employee of a utility grid operator, assert that "Resource managers often need scientific information to match their decisions (typically short-term and local) to complex, long-term, large-scale challenges such as adaptation to climate change. In such situations, the *most reliable route to actionable science is coproduction*, whereby managers, policy makers, scientists, and other stakeholders first identify specific decisions to be informed by science, and then jointly define the scope and context of the problem, research questions, methods, and outputs, make scientific inferences, and develop

[15] This is precisely the business pitch of a number of emerging risk analytics companies, such as Jupiter Intelligence, a Palo Alto start-up, which "provides climate change and weather event risk-prediction services…that deliver accurate, actionable information" about specific assets to a range of industry and government clients. "Creating a dynamic model that collects and analyzes data with such localized resolution is not a simple matter of 'downscaling' old methods," as their CEO pitches in an op-ed in *greenbiz.com* announcing the business. "It requires a different strategy and discipline, with single-site analysis as a core objective" (Sorkin, 2018).

strategies for the appropriate use of science." (Beier et al, 2016, 288; *emphasis my own*). While the "how-to" presents an idealized view of how actionability comes about, it also provides a suggestive blueprint for purposive action that is a cultural script in and of itself, whose circulation and effects are open to sociological and historical inquiry (Coen 2021).

Beyond the rhetorical and discursive levels, we can also see actionability increasingly being encoded within directives, laws and rules for how government should conduct itself with regards to climate change. In 2015, for instance, U.S. President Barak Obama issued an executive order requiring greater investments in flood protection when building federally funded infrastructure, especially critical facilities like hospitals. Before being allocated any funds, projects would have to account for "the elevation and flood hazard area that result from *using a climate-informed science approach that uses the best-available, actionable hydrologic and hydraulic data* and methods that integrate current and future changes in flooding based on climate science" and take steps to mitigate that hazard through design (Obama, 2015; *emphasis added*).[16] In another example, the 2018 Defense Authorization Act, without referring to "actionability", *per se*, nonetheless operationalizes the spirit of the idea by mandating that the military constructions incorporate changing environmental conditions into structure designs and modifications:

> *Not later than 30 days after the date of the enactment of this Act, the Secretary of Defense shall amend section 3-5.6.2.3 of United Facilities Criteria (UFC) 2-100-01 and UFC 2-100-02 (or any similar successor regulations) to provide that in order* to

[16] Obama's executive order was rescinded by President Donald Trump just days before Hurricane Harvey hit Houston in 2017, thus removing the consideration of climate change on federal reconstruction dollars. It was reinstated just recently by President Biden (June of 2021), so the effects of its call for "actionability" are not yet visible.

> anticipate changing environmental conditions during the design life of existing or planned new facilities and infrastructure, projections from reliable and authorized sources s*uch as the Census Bureau (for population projections), the National Academies of Sciences (for land use change projections and* climate projections*), the U.S. Geological Survey (for land use change projections),* and the U.S. Global Change Research Office and National Climate Assessment (for climate projections) s*hall be considered and incorporated into military construction designs and modifications.* (Federal Defense Authorization Act, 2018, p1589; *emphasis my own*)

In tracing the usage of this notion of actionability through what might appear a loose collection of evidentiary signposts (scientific conferences, policy commentaries, magazine articles and executive orders), I am making an argument about a shift in the relationship of climate science to a broader realm of collective action and meaning making. After what many have deemed failures of the initial science to instigate sufficient transformation of economic structures (i.e. rapid changes to the incumbent fossil fuel energy system) and social behaviour (i.e. consumption habits) to avoid major climate impacts, many organizations, communities and other social groupings are now seeking information that will help them navigate present and future climate risk. This interaction between decision-oriented demand and scientific output is happening at what I argue is an ill-defined, institutional interface where climate science is being actively translated to meet the interests and needs of these concerned collectives.

Government and the institutions of the state (i.e. the courts, statutes, and administrative agencies) clearly serve as one site of this interface of translation where the actionability of climate science is at stake, but it is hardly the only site. Or rather, these entities are themselves players in larger strategic action fields in which debates about preparing for climate change are taking place. By situating my analysis at the field-level, I propose tracing how the efforts of particular individuals or organizational subgroups represent the early institutionalizations of an everyday reckoning of climate impacts. My contention in doing so is to argue that by examining these interfaces and identifying the conflicts and spillovers that occur by trying to make information about climate change "actionable" we can also observe an emerging "politics of anticipation". The struggles to determine whose losses and which activities are being anticipated will increasingly shape how future climate impacts are socially distributed, and what kind of information is included and excluded from legitimate organizational action.

Data and Methods

To operationalize an empirical inquiry into actionability, my dissertation follows the circulation and use of climate data through case studies of three distinct organizational fields. While I focus on critical knowledge brokering organizations within each of these cases, the key unit of analysis is the organizational field itself, and how field-level dynamics (interaction between firms, citizen associations, non-profits organizations, regulators, scientists, and financial interests) produce institutional spillovers and other unintended consequences as different members of the field attempt to align uneven recognition of the fact that the future will differ from the past with present decision-making needs. As a result, each case elucidates the inter-organizational struggles of turning the uncertainty and variability of climate risks into objects of broader management and governance. The aim of my case selection is not comparative but rather extensive, sampling from the range of institutional settings where expectations about the future delivery of goods or services have been rattled by the specter of climate change. In each case, this experience of dissonance is being addressed by the deliberate effort of localized actors to incorporate climate knowledge into existing practices and systems of decision-making. Common questions arising within each setting include: What are field-level tensions encountered by actors undertaking translation efforts? How are these tensions managed, deflected, or even overtaken by other actors in the field? What alternative forms of knowledge or cultural practices do actors in these cases draw on in their projects of making climate knowledge actionable?

Responses to these questions were pursued using a mix of qualitative approaches across each case, including participant observation, semi-structured interviews, content and document analysis, and process tracing. Among these different techniques, participant observation in particular creates the opportunity to situate what people say within interactions and the social world in which their statements matter (Jerolmack & Kahn 2014). Thus, the language and emotion with which individuals in my cases discuss climate change and its relationship to their existing frames of decision-making was of particular interest to me across all of my settings. I paid particular attention to how individuals occupying different positions in their organizational-fields talked about the problems of extreme weather, climate variability and climate change, environmental non-stationarity, value and vulnerability, as well as how they talked about and made sense of the actions of other organizations in the (re)insurance, water management, and coastal protection fields.

This interpretive approach to the socio-cultural construction of actionability corresponds to relational approaches in qualitative research, which focus on flushing out "points of contact and conflict' between differently positioned actors, rather than assuming already determined, bounded categories of actors (Desmond 2014: 555). While I identify catastrophe modelers, industrial farmers, and coastal planners as key brokers in the knowledge politics around climate risk, my research also considers how the material artifacts engaged in decision-making processes also facilitate institutional relations. As such, I build on other ethnographic approaches looking at insurance and business contracts (Jarzabkowski et al 2015; Riles 2011), commodity and supply chains (Tsing 2004, 2015; Bakke 2016), and the development of science and technology (Latour 2003; MacKenzie 2006), to make claims about how material culture shapes collective agency and social outcomes, and to understand the conditions by which calculative devices both promote and erode institutional coherence (Mukerji 2015; Marres and Lezaun, 2011; Lehtonen, 2017).

Ethnographic field site data was collected primarily in the form of hand-written, qualitative fieldnotes that I typed up each night when I was in-the-field. These I compared with transcriptions from semi-structured interviews (across all cases, n=73) and notes from document analysis on an ongoing basis, allowing novel and conflicting information to lead me revise or generate new research and interview questions. Analysis of the data I gathered was conducted on both explicit and latent levels (with the two levels sometimes intersecting). Based on participants' experiences in bringing climate data into their work environments, I conducted an explicit analysis of what participants said in recorded interviews and observed interactions, to determine the nature of practical barriers and facilitative processes for translating climate modeling knowledge into techniques and tools for managing and reducing organizational risks.

On the latent level, I coded data related to the social and organizational dilemmas arising from the need to make decisions under conditions of uncertainty, as well as the need to assign or prioritize categories of valuation in the face of competing logics of worth (Boltanski and Thevnot 2006).

Rather than using an inductive approach (consistent with grounded theory; Glaser and Strauss 1967; Bryant and Charmaz 2010) in which themes are identified in the process of understanding the data, or a theoretical approach driven by predominant models or questions in the existing literature (as with extended case method; Burroway 1998), my analysis hewed closely to an abductive approach (Timmermans & Tavory 2014). Abduction is an inferential and analytic means for situating surprising empirical findings within a theoretical frame, harnessing this unexpectedness to promote greater understanding of the substantive and theoretical issues at hand. Transcriptions of my semi-structured interviews were anonymized in two out of three of the cases (cat modeling and coastal protection), whereas identifying information in the public water management case was retained with permission of my informants. Interview transcripts and field notes were coded by hand, and following abductive methods, I then grouped codes by larger conceptual categories that emerged from iterative rounds of analysis. In conducting the coding, the primary goal was to look for surprising relationships between emergent codes as well contradictions between my data and existing theory.

The underlying analysis for chapter two on catastrophe insurance draws on thirty-one semi-structured interviews with key informants from the (re)insurance field (conducted between January 2017 and April 2020). Semi-structured interviews were used as a means to develop a dense and descriptive mapping of the historical development of cat modelling techniques within US insurance markets. Interviews also served to triangulate some of the tensions and positioning of the different actors engaged in pricing homeowner premiums along the Gulf and Atlantic coasts following the 2004/2005 hurricane seasons. Individuals were selected for interviews because of their involvement in model development and their role in assessing catastrophe risk and managing the use of cat models in actuarial decisions, reinsurance purchasing and ratemaking. Since the specific identity of interviewees is unimportant to my analysis, information attributed to these interviews is anonymized.[17] Additional data include primary sources related to the development of the first catastrophe models as well as the specific events surrounding the 2005 model updates. These documents encompass testimony and regulatory filings from hurricane modelers to the Florida Commission on Hurricane Loss Projection Methodology (FCHLPM), public hearings before the National Association of Insurance Commissioners (NAIC) and select Congressional committees, letters from national consumer advocate associations to the NAIC, notes to clients on model updates from catastrophe modelers, insurance brokerage firms, and rating agencies, scientific publications authored by catastrophe modelling employees that accompanied the release of model updates, as well as local media coverage of these events.

The third chapter, on water allocation, is based on extensive ethnographic work conducted in the Southwest of France during a public campaign by the Adour-Garonne Water Agency to educate

[17] Interview participants included individuals from all three major catastrophe modelling firms (RMS, AIR and CoreLogic), two of the largest global reinsurance companies, two major (re)insurance brokerage firms, a large commercial property owner, a major US domestic insurance company, a national US consumer advocacy group, a former US Gulf-coast insurance regulator and West-coast insurance regulator, two hedge funds involved in developing and investing in catastrophe bonds and professional staff from the Departments of Insurance of the two most hurricane prone Gulf-states.

regional water stakeholders about future impacts of climate change on the river basin. This fieldwork included attending dozens of public meetings (some closed to the general public, but to which I was granted access) and forums organized by the Adour-Garonne Water Agency, the Watershed Committee of the Water Agency, the *Syndicat Mixte d'Études et Aménagement de la Garonn*e where water governance and planning measures were discussed and sometimes voted upon. I also engaged in participant observation of different actors in their daily interactions with water as 1) part of their livelihood (farmers, agricultural service providers, hydroelectric plant operators), 2) as part of their functions as members of state bureaucracies responsible for monitoring and maintaining the environmental health of the region's rivers (ONEMA, DREAL, *Université de Toulouse*), 3) as part of their advocacy work to protect or restore nature (nature conservation groups and landscape architects) or 4) recreate in the rivers (kayakers and fishing organizations). These moments of observation, which varied between roughly one to four hours were conducted over a wide swathe of the watershed and consisted largely of "tagging along" with individuals from these different groups on prescheduled activities, such as fish surveys, river bank restoration work, maintenance of irrigation systems, or corn planting. In tandem with these visits, I also conducted thirty-two semi-structured interviews with actors from all of the groups listed above.

Finally, data for chapter four, on the coastal protection efforts in the state of Louisiana, was gathered during three weeks of intensive field work to Louisiana in November of 2019, where I visited different coastal communities and conducted ten semi-structured interviews with state officials from the Coastal Protection and Restoration Authority (CPRA), the Governor's office, the Office of Community Development, the Department of Insurance, coastal engineers, landscape architects, oystermen, and members of the Pointe-au-Chien Indian Tribe. Other documents reviewed include scientific articles on Louisiana's wetland loss, state budget and economic analyses, rating agency reports, and a wide range of planning documents, criticism, newspaper accounts, and prior restoration plans predating the CPRA's current Coastal Master Plan.

Chapter Outline

Below is a table organizing multiple framings and components of actionability across the cases followed by an extended description of each chapter:

	Disaster insurance	Water allocation	Coastal protection
Scale	National/Continental	Regional/Major watershed	Local/Deltaic Plain
Institutional arrangement	Regulated market	Public administration of common resource	State land-use planning
Climate Risk	Extreme weather / hurricane winds	Drought / incremental ecosystem drift	Flooding / land erosion
Climate Data	Global Circulation Model (GCM) data on sea surface temperature and other hurricane genesis parameters	Downscaled GCM data on surface temperatures and regional precipitation patterns	GCM and semi-empirical modeling data on sea level rise
Authority	State-level insurance regulation Private regulation (i.e. rating agencies)	National legislation European Union directives	State funding agency
Decision making devices	Catastrophe models (meteorological, engineering, and financial expertise)	Hydrologic and irrigation demand models / ecological baseline metrics	Integrated Compartment Model (ICM) / decision optimization model (i.e. multi-criteria cost-benefit-analysis)
Representative metric / idiom	100-year storm Exceedance Probability Curve	Minimum Flow Rate (MFR) Withdrawal Right (WR)	Acres of avoided land loss Flood depths
Type of Economic Relations	Private property Insurance contract Risk markets	Public service delivery Agricultural commodity Tragedy of the commons	Tax revenue Public debt
Moral Dimensions	Fairness Actuarial soundness	Ecological integrity Rural livelihoods	Sacrifice zones Regulatory capture
Motivation/Compulsion	Physical loss events Pressure from reinsurers Competition	Prospection Policy entrepreneurs	Major disaster Loss of a "way of life"
Object of Politics	Premium prices Building codes Private property	Public infrastructure (retention dams) Private extraction (irrigation systems) Patrimonial species (salmon, lamprey, etc)	Public infrastructure (dikes, sea walls, etc) Wetlands Sovereign territory Creole identity

Table 1.1: *Varying dimensions of actionability across three field-level settings*

Hazardous simulations: Pricing climate risk in U.S. homeowner insurance markets

The advent of climate change has brought concerns that extreme events – i.e. hurricanes, wildfires and droughts – are diverging from their past patterns of occurrence (Melillo et al, 2014; Willner et al, 2018). As a result, financial markets are devoting increasing resources to improve the evaluation of climate impacts for current and future investment decisions. The core business of the (re)insurance sector is particularly vulnerable to this shifting baseline, since many of its methods for pricing risk rely on a stable historical record from which the likelihood of future hazards can be forecast. Climate change undermines the basic premise of historicity upon which actuarial statistics depend, opening up the need for new approaches to characterize and certify the risks property holders face from climate impacts. A key node in this emerging field of climate risk analytics is a small group of firms called catastrophe modellers, or cat modellers for short. In chapter two, I examine the role cat modelers play in shaping insurance market responses to climate risk particularly in hurricane exposed areas of the United States. Efforts to improve cat model designs by incorporating information on climate change have generated contentious reactions among citizens and regulators affected by the increases in insurance prices wrought by these changes. Outcomes of these modeling conflicts, as the case explores, have wider repercussions for homeowners, homebuilders and the real estate sector as well as state and municipal finances.

Taking a genealogical approach, I trace the emergence of the first cat modellers Applied Insurance Research (AIR) and Risk Management Solutions (RMS) in the late 1980s in the U.S., follow the rapid integration of cat models into U.S. insurance markets in the wake of Hurricane Andrew in 1992, and then examine how subsequent efforts to incorporate climate change data into cat models created a crisis of confidence in the firms' risk-estimate figures and a rejection of their products and "climate-enhanced" techniques by regulatory authorities. At the same time that they were being sanctioned by state regulators, the industry's services were also being increasingly solicited by actors in the capital markets looking for unconventional data to design new investment products – catastrophe bonds and other "insurance linked securities" – that have opened a new zone of accumulation and competition in risk markets. Finally, this case also foregrounds the question of whether the distribution of additional layers of "climate risk" through insurance or other private risk-transfer mechanisms actually helps communities prepare to withstand these kinds of catastrophic events and/or recover as quickly as possible once they have passed. In other words, what kind of catastrophes do catastrophe models help perform (MacKenzie, 2006) and what options to they provide for approaching catastrophes differently?

Cultures of anticipation: Material practices, public authority, and governing water scarcity

Rivers are among the ecological systems most sensitive to climate change. A great deal of aquatic life evolved to survive within narrow fluctuations of temperature and pH levels characteristic to specific rivers (Hasler et al, 2016; Weiss et al, 2018). As waters heat and also become more acidic, conditions for many aquatic species deteriorate, in some cases to the point of making rivers inhospitable to previous members of their ecosystem. In addition, much human habitation is located or dependent on river systems for its drinking water supply, trade, transport and agriculture. Changes in ambient temperature, precipitation and snowmelt rates affect the availability of water for all of these different uses, putting stress on the competing constituents of water as well as the institutions designed to mediate these different uses. The Garonne River in the southwest of France is an example of a river that climate models suggest will face increasingly long months of low water flow, especially in the months of July, August and September, when demand on the river system for irrigation is at its highest. The administrative body responsible for governing this ecosystem resource, the Adour-Garonne Water Agency, has undertaken a broad scale effort at engaging water users in the region with projections of future climate change in order to help the agency think through how best to adapt its priorities to meet future climate challenges. The Agency conducted a three-year public campaign (2012-2014) to sensitize and solicit participation from local water users at public forums about how to manage this new problem, hewing to a process of consensual planning to which the Agency aspires.

After decades of struggle between different "user groups" – pitting especially environmentalists against farmers – the agency pioneered in 1991 a new accord that structured water management around Minimum Flowrate Targets (MFT; in French, the *débit d'objectif d'étiage,* or the *DOE)*. Calculating the MFT involves a systematic measuring in real-time the flow rate at dozens of monitoring stations spread throughout the river basin. When flow rates drop below the negotiated levels (set to protect biological life), local authorities are required to issue restrictions on irrigation withdrawals from the river. This tentative social contract around water use, eventually adopted across each of France's major water basins, is now being called into question (and reopened for negotiation) as climate change is expected to push flow rates lower for longer periods of time. The existing rates, in other words, were calculated for a world that may no longer exist. This situation is raising a number of questions: How much humans can do to regulate and protect nature in the face of a changing climate? Since climate adaptive measures cannot be applied with equal proportion to all user groups, who gains and who loses from new rules governing water use? And how does the administrative state approach the political task of dis-incentivizing certain economic activities (such as growing corn) that it actively encouraged and subsidized in the not-so-distant past? This chapter responds to previous research in valuation studies, examining the techniques and processes used to try and commensurate different values such as the economic worth of water versus its ecological integrity (Espeland 1998). It considers the role of non-human "constituents" (i.e. irrigation infrastructure and water monitoring devices) in representative democratic systems (Latour, 2004b), as well as borrows framings from anthropology to help understand how new material practices do not simply respond to, but also enact, climate-altered ecosystems (Tsing, 2015).

The Treadmill of protection: How public finance constrains equitable climate adaptation

The final chapter takes up a case in Louisiana where the coastal wetlands of the Mississippi River delta, the sixth largest in the world, are eroding at an alarming rate, exposing the state to shrinking sovereign territory and increased exposure to flooding from sea level rise. The sinking of Louisiana's coastal wetlands provides a clear example of Anthropocene trends of accelerating local vulnerability due to human-induced environmental change. With the bulk of state revenue tied to activities concentrated along Louisiana's coasts, the state's Coastal Protection and Restoration Authority has launched an ambitious plan of government-backed planning and expenditures that seek to defend the economic viability of these zones. Yet, many actions aimed at preventing immediate loss also work to secure incumbent extractive industries, such as offshore oil and gas drilling, which themselves contribute to the very vulnerabilities requiring state intervention in the first place. Borrowing from Allan Schnaiberg's environmental sociology, I consider the social consequences of this dynamic, which I dub the "treadmill of protection."

I show in this chapter how making knowledge about climate change "actionable" can be captured by powerful economic sectors to which state actors and state programs are beholden. To state the problem at a general level: As the physical impacts of the Anthropocene begin to make themselves felt around the globe, maintaining current levels of economic prosperity, in many communities, will consume an increasing portion of public finances. This is because existing investments in property and capital will require new forms of protection if they are to continue generating stable streams of public revenue. Since Anthropocene impacts are unevenly distributed, some territories will be under more pressure than others to shift limited public spending to cope with growing levels of exposure. As the chapter makes clear, public officials' (particularly in liberal democracies) dependence on the fiction of continual economic growth bind them into defending the most "productive" economic sectors, despite their damaging effects on future economic wellbeing, in order to continue providing other public goods and services. Breaking out of this treadmill requires rethinking categories of growth and loss.

Conclusion

This dissertation deals with the question of how societies are beginning to cope with the expansion of risk caused by climate change through the institutionalization of "actionability" within existing mechanisms and technologies of contracting, resource governance, and service delivery. As each case shows, this process of institutionalization happens in a fragmented and uneven way, driven by conflicting interests and efforts by particular groups to determine which climate knowledge should be turned into actionable information. By bringing together perspectives from political sociology, science studies, and the sociology of risk, and drawing on ethnographic and other qualitative methods, this dissertation contributes to understandings of the ways in which anticipating the future is a growing domain of politics. It does this by scrutinizing the processes by which knowledge about environmental change becomes institutionalized, and shows that this scrutiny is necessary in order to evaluate for whom, and for what, climate information is made actionable.

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Chapter 2

Hazardous simulations: Pricing climate risk in US coastal insurance markets[18]

In December 2005, members of the National Association of Insurance Commissioners (NAIC) convened at the Sheraton Hotel in Chicago to discuss the fallout from two record-breaking hurricane seasons. Between 2004 and 2005, 25 hurricanes and tropical storms had pummeled US coastal communities, causing hundreds of billions of dollars in damages and claiming the lives of nearly 2,000 Americans. The NAIC, made up of state-level US regulators responsible for overseeing local insurance markets, was intent on making sure that insurers met their obligations to help homeowners rebuild. But the NAIC was also concerned by another issue: that the spate of recent storms was a harbinger of worse things to come. A growing body of science pointed to the exacerbating influence of climate change on extreme weather events and the officials wanted to know whether this was true, and what, if anything, they should do about it.

Among those addressing the group was Robert Muir-Wood, Chief Research Officer of the catastrophe-modelling firm Risk Management Solutions (RMS). In his presentation at the Sheraton, Muir-Wood suggested that the computerized weather simulations insurers used to forecast hurricane risk – like those designed by RMS – were no longer adequate for creating accurate damage estimates. 'We've gotten to the point where climate change needs to be included when thinking about modelling for the near future' (NAIC, 2006, p. 89). According to Muir-Wood, bringing climate change into these models, known as catastrophe, or 'cat' models, would allow signals about 'climate risk' to begin working their way into insurance markets. This would shift how individuals made decisions about where to build and purchase future homes,

[18] A version of this chapter appeared in 2021 in the journal *Economy and Society* 50(2): 196-223

helping protect individuals from making bad choices while also reduce the underlying exposure to the whole industry.

In fact, Muir-Wood told the audience, RMS was already working on a solution. Just a couple months before the NAIC meeting, the company 'convened a session involving three key climatologists that represent different perspectives on planet change, with considerable depth of knowledge of all facets of hurricane activity [and] hurricane climatology'. The result of this 'expert elicitation' was that 'we actually got them to arrive at a consensus on what was going to be the activity of hurricanes at landfall as well as in the basins over the next five years' (NAIC, 2006, p. 93).

Cat models shape perceptions of risk, and these perceptions structure conversations between insurers, reinsurers, regulators, brokers, rating agencies and consumer advocates about how to fix homeowner premiums, establish capital adequacy requirements, make decisions about purchasing reinsurance, and evaluate the financial health of insurance companies. In the United States, the setting of premium rates involves annual negotiations between insurers and the very individuals gathered in Chicago listening to Muir- Wood's presentation.[19] When RMS finally released its new hurricane estimates, however, it became clear that incorporating climate risk into homeowner insurance would lead to major premium increases along the Gulf and Atlantic seaboards.[20] As a result, rather than forging a new consensus about natural disaster risk, the

[19] The US insurance market, through a quirk of federalism, is regulated at the state level, creating 50 different insurance markets. Individual state insurance regulators are often political positions: in 11 states these are elected positions, while in 19 states the governor appoints the regulator (cf. Lehmann, 2018). As a result, US property and casualty markets tend to be more politicized than other mature insurance markets such as in Europe or Japan.
[20] Cat models have evolved to cover a wide range of perils. This paper focuses specifically on efforts to model the 'wind' peril from hurricanes; flood damages from storm surge are also modelled, but not subject to inclusion in ratemaking, since flood risk in the United States is currently assessed by federally determined Flood Insurance Rate

climate-enhanced model provoked strong dissent from those most affected – consumer advocates, homeowners and the public officials who represented them. Loathe to raise rates on their constituents, regulators rejected applying the model to future windstorm premiums, betting (and hoping) that storm activity would remain more or less unchanged (Interview with regulator from Florida Office of Insurance, telephone, 7 August, 2019).

This failure to achieve agreement on model updates sheds light on how insurance, and the often invisible and mundane practices of risk assessment, serve as an increasingly crucial terrain over which people are struggling to define how and when climate change should be institutionally taken into account. RMS' effort to improve its models was driven by a credible scientific concern that future weather could no longer be inferred by past trends. This concept of a baseline climate around which weather varies in a statistically dependable fashion – called 'stationarity' – seemed less and less valid with respect to hurricanes. But the elicitation of expert opinion about the behavior of future storms represented a radical shift in how catastrophe-modelling firms measured hurricane activity.[21] And a 'non-stationary' approach to event simulation threatened to unravel a web of embedded social assumptions about the relationship between insurance pricing, real estate development, economic growth and the American Dream of homeownership in places such as Florida, South Carolina and Louisiana.[22]

Maps (cf Elliott, 2017), although this is beginning to change and cat modelling is playing an increasing role in shifting the calculation of flood hazard toward parcel-level assessments.

[21] Elicitation is a widely used tool of risk assessment for catastrophic events with little to no record of occurrences (e.g. nuclear reactor meltdowns or terrorist attacks), but it is 'radical' in the context of evaluating the price of homeowner insurance.

[22] Paul Pierson (2004) argues that institutions often persist because they draw legitimacy from complementary sets of supporting institutions. It is fruitful to think about US homeownership in this context of embedded and interdependent institutional relations.

Drawing on this extended episode in the life of a catastrophe model, this paper examines the uneven consequences of efforts to make climate change information meaningful for realms of economic decision-making. Situating cat models within a broader genealogy of insurance technologies, the paper builds on perspectives from the sociology of risk showing that insurance operates not as a singular form of knowing, but through 'combinations' (Bougen, 2003; Ewald, 1991) or 'assemblages' (Collier, 2008; Dean, 1998) of practices that simultaneously assess and assign responsibility for risk (Ericson & Doyle, 2004a). Cat models, I argue, overcome conditions of actuarial uncertainty by creatively translating different modes of calculation – what Ian Hacking (1992) calls 'styles of reasoning' – into the singular idiom of statistical probabilities. This epistemological creativity, however, is constrained by the need of cat modelers to maintain the institutional legitimacy of their risk evaluation techniques, pitting experts' scientifically plausible approaches to forecast future storm conditions against the problematic political effects these forecasts have on how risk is socially distributed.

Additionally, this paper focuses on a particular set of (re)insurance actors – catastrophe modelling firms – who are deliberately trying to assess climate science in an effort to reconcile forecasts of change with the profit-making imperatives of insurers. In doing so, I want to turn attention away from the oft-analysed cases of corporate denialism and obfuscation of climate change (Brulle, 2014; Farrell, 2016; Jacques et al., 2008), toward private sector actors who embrace the science. Unlike Oreskes and Conway's (2010) merchants of doubt, who are in the business of delegitimating climate science for capital gain, cat modelers are trying to edge out their competition by legitimating the science. Thus, the paper extends previous analysis in STS of the role climate modelling plays in shaping public agendas of environmental governance

(Edwards, 2010; Heymann et al., 2017; Howe, 2014) to look at how climate-related knowledge is being woven into private technologies of risk assessment to influence mundane economic activities, such as the underwriting of homeowner insurance.

The paper proceeds in five parts and begins with (i) a consideration of the problem of climate change in the context of other sociological accounts of insurance (understood as an institutional blend of expertise and political rationalities that mutually shape the governance of risk); (ii) a brief presentation of the paper's data and methods; (iii) a history of the development of cat models and their initial success in creating social consensus around catastrophe loss estimates; (iv) an analysis of the 2004/2005 North Atlantic hurricane seasons as a pivotal moment where the introduction of 'non-stationary' modelling practices disrupts the shared acceptability of model outputs; and (v) concludes with a discussion of how expert efforts to institutionalize climate risks into insurance pricing presage a growing category of political struggles over how to distribute responsibility for the increasing burdens of climate change.

Catastrophes, climate change and the question of insurability

Sociologists have long been interested in understanding how insurance structures social and economic attitudes toward the future (Ewald, 1991; Giddens, 1990; Reith, 2004). Prominent among early studies was Ulrich Beck's Risk society (1992a), in which he identifies insurance, and its ability to spread the negative consequences of specific events across a population of uncorrelated individuals, as a key motor of modernity. For Beck, insurance serves to socialize risk, softening in particular the dangers that industrialization posed to the health and safety of workers and citizens: 'Modernity, which brings uncertainty to every niche of existence, finds its counter-principle' as Beck writes, 'in a social compact against industrially produced hazards and damages, stitched together out of public and private insurance agreements' (Beck, 1992b, p. 100; emphasis from the original).[23]

Yet, the same technological and economic progress associated with early modernity, according to Beck, also paradoxically threatens society with new classes of 'post-industrial' hazards – e.g. nuclear accidents, technologically accelerated epidemics and rampant genetic modification. Not only is it difficult to estimate the likelihood of these catastrophic events (due to their extreme rarity), but also of socializing any subsequent damages if they do occur (because of their systemic nature). Thus, post-industrial catastrophes undermine the political function of insurance as a means of providing security against modern life's random but calculable hazards.

Climate change, for Beck, serves as a quintessential case of this new class of hazards since it results from the very burning of fossil fuels that provided the basis for industrialization in the first place (Beck, 2008). In addition, the impacts of climate change are difficult to predict within the scales of time and space typically involved in existing frameworks for distributing risks (Bulkeley, 2001; Levin et al., 2012). For Beck, this twin problem of the 'incalculability' and 'unspreadability' of damages from post-industrial hazards anticipates the demise of traditional risk mitigation mechanisms, such as private insurance. In this context, climate change points to a new landscape of 'conflicts of accountability' as social disputes erupt over how the

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[23] Despite the notion of 'counter-principle', the development of insurance should not be read as something that happens in contra-distinction to capitalism: 'The socialization of risk does not seek to undermine capitalist inequality, precisely the opposite. It is a means of treating the effects of that inequality' (Dean, 1998, p. 31).

consequences of new 'risk(s) can be distributed, averted, controlled and legitimated' (Beck, 1996, p. 28).

While Beck put his finger on theoretically salient problems, recent research in the sociology of risk suggests that actuarial techniques for assessing and transferring risks are more adaptable than he initially supposed (Collier, 2008; Dean, 1998; Johnson, 2014; O'Malley, 2004). For instance, computer simulations, packaged commercially as catastrophe models, have allowed insurers to extend their markets even in the face of growing types of uncertainty (Bougen, 2003). These devices operate as alternative forms of calculation that expand the instruments and instances through which risk – particularly property and casualty risks – can be economized. As Stephen Collier (2008) has noted, simulation technologies represent a different assemblage of calculative techniques than the predominantly probabilistic frameworks that Beck considered indissociable from private insurance. By exchanging one 'style of reasoning' (what Collier calls 'statistical archival' reasoning) with another (what Collier calls 'enactment'), simulations help render more manageable the uncertainties heralded by extreme forms of risk. In doing so, they extend the social compact of private insurance beyond the limits initially proposed by Beck (Bougen, 2003; Ericson & Doyle, 2004b).

Cat models, for instance, reinforce traditional forms of risk transfer by expanding the role of reinsurance contracts and securitized forms of property risk called catastrophe bonds within local insurance markets (Jarzabkowski et al., 2015; Johnson, 2014). Yet, as cat modelers (under pressure from these higher order risk aggregators) try and come to terms with growing evidence that past data on losses is no longer predictive of future disasters, their adjusted hazard assessments are prone to cause major dislocations at the level of domestic policyholders. By increasing perceptions of risk in the private markets of property and casualty insurance, cat modelers participate in a mode of governing risk that further individualizes the responsibility of homeowners to bear the burden of climate risks (O'Malley, 1996). This is despite the fact that, for many individuals, the decision to live on the coast was both encouraged and supported by the very system of private insurance now attempting to hold them accountable for a choice that might have occurred long in the past.[24]

The conflict that ensues between actors operating at different scales of the insurance field serves as a case study in how the institutionalization of climate risk depends not just on the accuracy of future damage estimates, but on addressing concerns about who should bear the burden of increased perceptions of risk. In other words, returning to Beck, technical advances in risk assessment do not address the underlying problems climate change poses to current social arrangements of insurance: How, in a world where the evaluation of risks grows to encompass horizons of choice that stretch backward and forward in time, do institutions of risk governance adjudicate the responsibilities tied to those decisions?

Data and Methods

[24] What I mean by this is that for many individuals, the 'choice' to live on the coast was potentially influenced by decisions made generations ago by a grandparent or prior ancestor; made perhaps with the hope of being able to pass along property to future descendants. When these initial choices were made, there was no inkling of the problems of climate change, either for homeowners or the insurance industry. Other individuals, however, are making these decisions contemporaneously, even in the face of well-mediatized information about future coastal impacts from climate change. Cat models, like the rest of the private insurance market, do not differentiate between the temporality of 'choices' to live on the coast. For the ethics of risk temporalities see Elliott (this issue).

The underlying analysis in this paper draws on 27 semi-structured interviews with key informants from the (re)insurance field (conducted between January 2017 and August 2019). Semi-structured interviews were used as a means to develop a dense and descriptive mapping of the historical development of cat modelling techniques within US insurance markets. Interviews also served to triangulate some of the tensions and positioning of the different actors engaged in pricing homeowner premiums along the Gulf and Atlantic coasts following the 2004/2005 hurricane seasons. Individuals were selected for interviews because of their involvement in model development and their role in assessing catastrophe risk and managing the use of cat models in actuarial decisions, reinsurance purchasing and ratemaking. Since the specific identity of interviewees is unimportant to my analysis, information attributed to these interviews is anonymized.[25]

Additional data include primary sources related to the development of the first catastrophe models as well as the specific events surrounding the 2005 model updates. These documents encompass testimony and regulatory filings from hurricane modelers to the Florida Commission on Hurricane Loss Projection Methodology (FCHLPM),[26] public hearings before the National Association of Insurance Commissioners (NAIC) and select Congressional committees, letters

[25] Interview participants included individuals from all three major catastrophe modelling firms (RMS, AIR and CoreLogic), two of the largest global reinsurance companies, two major (re)insurance brokerage firms, a large commercial property owner, a major US domestic insurance company, a national US consumer advocacy group, a former US Gulf-coast insurance regulator and West-coast insurance regulator, two hedge funds involved in developing and investing in catastrophe bonds and professional staff from the Departments of Insurance of the two most hurricane prone Gulf-states.

[26] The FCHLPM is an advisory commission to the Florida Office of Insurance Regulation (FLOIR) composed of experts in the field of meteorology, weather modelling, engineering and finance that reviews the models used for ratemaking in the state of Florida. The FCHLPM is currently the only state-level commission in the United States with the technical capacity or public mandate to review the scientific assumptions of catastrophe models. The Commission does not pass regulations itself, but advises the FLOIR on which models meet approved standards for the purposes of ratemaking. Almost every other coastal state insurance office in the US follows the lead of the FCHLPM. As a result, it acts, for all intents and purposes, as the sole forum for scrutinizing cat models and holding them publicly accountable.

from national consumer advocate associations to the NAIC, notes to clients on model updates from catastrophe modelers, insurance brokerage firms, and rating agencies, scientific publications authored by catastrophe modelling employees that accompanied the release of model updates, as well as local media coverage of these events.

Institutionalizing risk metrics for 'small-number' hazards

To appreciate how climate change upends current forms of estimating catastrophe losses, we must understand how catastrophe models succeeded in creating legitimacy around a particular set of risk assessment techniques in the first place. Prior to cat models, property and casualty insurers largely avoided underwriting for natural disasters (e.g. floods, earthquakes and hurricanes). Because of their rarity, these extreme events do not conform to what statisticians call the 'law of large numbers', the type of regularly occurring event sets that create the conditions for probabilistic analysis (Desrosières,1998). But in the late 1980s, techniques emerged that offered insurers a relatively standard framework for quantifying catastrophes through computer simulation, making natural disasters and other improbable but devastating events subject to more traditional methods of actuarial pricing (Grossi & Kunreuther, 2005).

Synthetic storms and statistical norms

The idea that computer simulations could be leveraged to fill in blank spots in insurers' knowledge of natural disasters was proposed as early as the 1960s by Don Friedman (1975), Director of Research at Travelers Insurance. Building on Friedman's work, Karen Clark, a former research engineer with the US branch of British Commercial Union, presented 'A formal approach to catastrophe risk assessment and management' at the 1986 annual meeting of the Casualty and Actuarial Society.[27] Sensing the potential for a new business service, Clark went on to launch the first cat modelling firm – Applied Insurance Research (AIR), based in Boston (Jahnke, 2010). Almost simultaneously on the West Coast, Stanford Business School graduate Hermant Shah and a doctoral student in civil engineering, Weimin Dong, created Risk Management Solutions (RMS), a cat modelling firm that initially specialized in forecasting earthquake risk (commercializing research conducted by Shah's father and Dong's PhD advisor, Stanford Engineering Professor Haresh Shah) (Muir-Wood, 2016). AIR, meanwhile, focused on improving estimates of North Atlantic hurricane risk.

Beginning with the sparse record of landfalling hurricanes maintained by the National Oceanic and Atmospheric Administration – called HURDAT – Clark proposed using numerical simulations of past storms to augment the number of possible hurricane events that might strike a insurers' portfolio of properties. By stochastically sampling from the historical storms' primary parameters (e.g. minimum central pressure, radius of maximum winds, forward speed and track direction of the storm) and recombining them using Monte Carlo techniques, Clark produced tens of thousands of plausible, 'synthetic' storm events. In doing so, she leveraged a 'small-number' data set into a big population of computer-generated storms, translating rare weather

[27] Clark's initial cat modelling scheme was itself deeply reflective of the combinatorial creativity that Ewald (1991) and Bougen (2003) note as constitutive of insurance technologies. Clark borrowed extensively from Friedman's computational structure, particularly with regard to modelling exposure of the built environment (what Friedman called the 'vulnerability module' of the model). But in a fruitful act of bricolage, she enhanced Friedman's deterministic simulation of storm events (the 'hazard module') by drawing on the work of Canadian wind engineer Alan Davenport and his collaborators, who had introduced stochastic, Monte Carlo simulations of hurricanes to statistically characterize the full range and distribution of wind events that might affect building projects for which Davenport's firm served as structural engineering consultant (Georgiou et al., 1983).

events into the idiom of the 'law of large numbers' and the framework of probabilism that governs the majority of insurable risks (Collier, 2008; Ericson & Doyle, 2004a).[28]

By drawing on the entire record of past storms, Clark premised her analysis on what I call 'stochastic impartiality'. Her simulations relied, like many probabilistic calculations in the insurance industry, on the notion of long-term averages and indifference to year-on-year variation. As other scholars have pointed out, developing impartial techniques of risk assessment has been a fundamental condition for the success of insurance as an institution. Significant innovations in both health insurance and fire insurance, for instance, were driven by efforts to provide contentious consumers and doubtful regulators with evidence that premiums were not based on arbitrary or biased calculations (Bühlmann & Lengwiler, 2016; Porter, 2000; Schneiberg & Bartley, 2001). The cat models accomplished a similar function, fulfilling the conditions for what the historian of science Ted Porter (1995) calls a 'trust in numbers'. Like insurance technologies before them, they proposed a 'shift away from informal expert judgment toward reliance on quantifiable objects' that promoted 'public standards over private skills (Porter, 2000, p. 226).[29]

Social compact under stress

[28] At the time of Clark's, 1986 article, HURDAT covered roughly 151 landfall hurricane incidents going back to 1900; that number has grown in the past 30 years to include 49 more storms, or less than two per year. Not a large number. The HURDAT dataset is available at http://www.aoml.noaa.gov/hrd/hurdat/All_U.S._Hurricanes.html (Last accessed on 04/09/2019).

[29] This is not to suggest that the models erase informal or tacit knowledge in the process of assessing and insuring cat risks. Ericson and Doyle (2004a) write convincingly that such practices are irreducible to how insurance functions since decisions about risk depend also on aesthetic, emotional and experiential judgments (see also Jarzabkowski et al., 2015; O'Malley, 2004). Following Porter, what the models achieve is a displacement and re-embedding of discretion into denser structures of formal standards and professional norms, although others (particularly Weinkle & Pielke, 2017) have questioned the accountability of these standards since significant portions of the models remain proprietary and inscrutable by the public or its representatives.

Despite cat models' sophistication, insurers were not initially unconvinced of the problems the models claimed to solve – i.e. that underwriters were overexposed to catastrophe risks. The situation changed rather dramatically after a string of major natural disasters at the end of the twentieth century caught insurers' attention (Hurricane Hugo, 1989; Hurricane Andrew, 1992; the Northridge Earthquake, 1994; and the Kobe Earthquake, 1995). Hurricane Andrew, in particular, caused a panic after a group of 11 insurers in Florida went bankrupt by underestimating their exposure to wind loss from the Category 5 storm (Jahnke, 2010; McChristian, 2012).[30] As a result, roughly 16,000 homeowners suffered $465 million in unpaid insurance claims that the state had to eventually step in and cover (Wilson, 1992). As public officials worked to hold companies accountable for outstanding contracts, insurance companies debated whether to continue underwriting at all in the state. This put additional pressure on officials to find ways to coax still solvent insurers to renew homeowner policies for the coming hurricane season (Trigaux, 1993; Wilson, 1993).

Contemporaneous newspaper stories capture local Floridians' worries about the repercussions of a world without hurricane insurance. 'Coastal residents, or potential coastal residents', according to one article, 'may have trouble financing their homes because lending institutions require the windstorm coverage'. As a result, 'Residents, coastal officials, local bankers, insurance agents and builders [are concerned] that new insurance restrictions will destroy the county's coastal residential market' (Thompson, 1993). These press accounts capture the network of local commitments and individual aspirations held together by the 'social compact' of insurance (Beck

[30] Insurance companies had more or less pegged the upper end of catastrophic loss in Florida at $4 billion, based on the previous record-setting losses from Hurricane Hugo. With Andrew, they were off by a factor of four (McChristian, 2012).

1992b), as well as the threat of its potential undoing – the collapse of local property values. As one Republican legislator from Tampa quipped to a regional newspaper, ‘We all recognize that insurance is not a luxury. It is very much a necessity’ (Moss, 1993).

Cat models arrived as a response to multiplying concerns, providing a set of stable representations of catastrophe risk that helped convince numerous stakeholders of the need for premium hikes. AIR’s model, which had estimated $13 billion in potential damages before Hurricane Andrew struck land, tracked tightly with actual losses and quickly emerged as an ‘obligatory passage point’ (Callon, 1986) not just for anxious actuaries but for the entire field of (re)insurance (Grossi & Kunreuther, 2005). By impartially sampling across the full historical data set of storms, cat models promised to smooth out the knee-jerk premium increases that had plagued the industry following previous cycles of catastrophes, building future price increases into current premium rates by averaging losses across long scales of time (Interview with former Gulf state Insurance Commissioner, telephone, 26 October, 2017). As a result, the models forged a new consensus about rate increases not only in Florida, but across all US coastal property markets.

Perceptual unification and field reconfiguration

The integration of simulation techniques into the regulatory circuitry of insurance pricing rapidly reconfigured discussions in the property and casualty sector around the central cat model output – the Exceedance Probability (EP) curve. A simple, right-facing, downward sloping line (see *Figure 1*), the EP curve synthesizes the risk of future disaster and shapes negotiations about the price of property insurance between regulators, insurers, reinsurers, capital markets and other stakeholders (Jarzabkowski et al., 2015). The EP curve gives this constellation of actors an aggregated view of risk over a given return period (typically 10 years), called the annual average loss (AAL), as well as an idea of the probable maximum loss (PML) for a specific event in any given year (say the loss from an event with a 0.4 per cent chance of occurring, what is colloquially called a 1-in-250-year event).

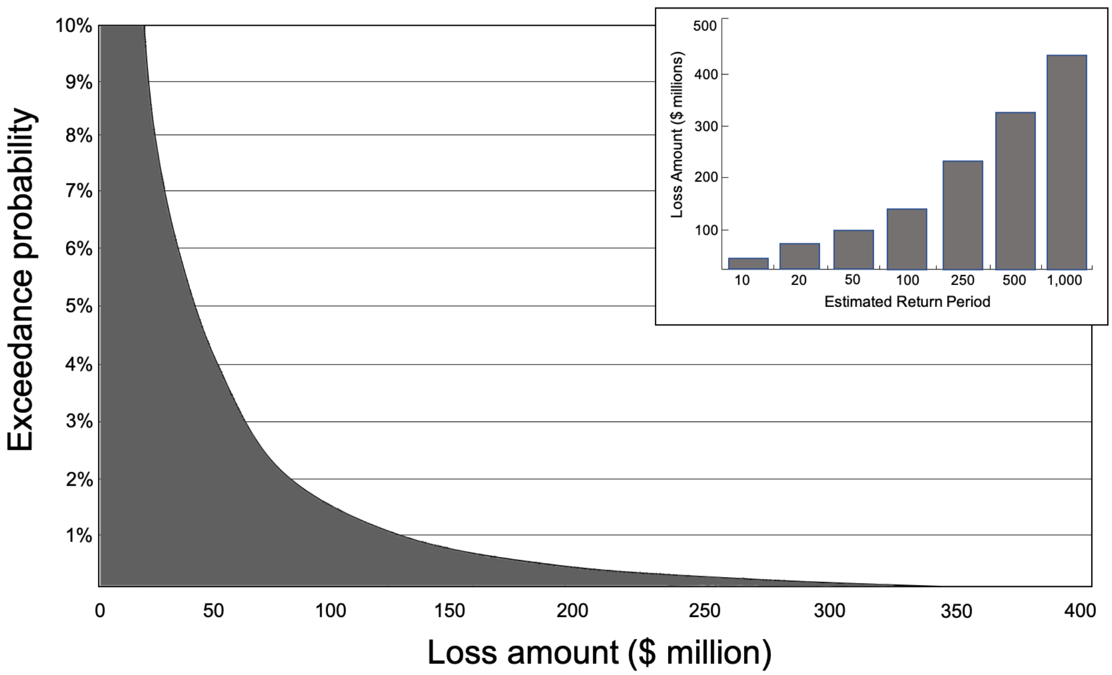

Figure 2.1. *Stylized version of an Exceedance Probability Curve (Based on Clark, 2002).*

One of the principal reasons that so many insurers went under after Hurricane Andrew was because they lacked sufficient amounts of reinsurance. Reinsurers provide insurers access to capital (at a price) in case of large, catastrophic losses – an insurance policy for insurers. Following Andrew, reinsurers were understandably reluctant to offer significant new 'capacity', to the Florida market (Stark, 1993). The cat model's ability to provide a PML, however, helped pave the way for increased participation from the reinsurance sector across the Gulf coast and Eastern seaboard as risk perceptions of insurers, reinsurers and regulators converged around the same probability curves.[31] By transforming the question of 'how do we prevent the collapse of the insurance sector' into 'what does the EP curve say about the loss potential for an aggregated set of exposures', the cat models successfully translated new uncertainties about hurricanes into the traditional insurance logic of pooled risk spreading, albeit with a larger role for both private and public reinsurance.[32]

This influence, however, would prove to be double-edged, as new concerns –brought on by another record-breaking season of storms, as well as emerging research on climate variability and climate change – challenged cat modelling firms to account for a world where hurricane risk was no longer assumed to be constrained by a historical baseline. Navigating this new and uncertain knowledge, the response of cat modelers to this notion that the past is no longer predictive of the future threatened to undermine their hard-earned legitimacy as trustworthy purveyors of disaster loss. If stochastic simulations overcame the problem of small-number hazards by translating them into the risk idiom of probabilism, climate change troubled assumptions around stochasticity, and with it, the tenuous political settlements achieved by the 'stationary-view' of hurricane risk.

[31] While I have been using Hurricane Andrew to analyze the impact of cat models on hurricane insurance, the metrics of PML and AAL have become institutionalized for a wide range of global catastrophe perils. On the one hand, the PML figures prominently in negotiations between reinsurers and local insurance companies regarding triggers or attachments points for reinsurance contracts; discussion between insurers and regulators, on the other hand, tends to focus more on the AAL, which helps create consensus about the minimum amount of premiums primary insurers need to collect in order to maintain adequate reserves in the case of not just 'cat' losses, but losses from smaller storms as well (what are known in the industry as 'kittens').

[32] . In addition to increasing the position of reinsurance companies in cat risk markets, Andrew also pushed exposed states to strengthen residual insurance markets by creating public reinsurance schemes. In 1993, the Florida legislature created the Florida Hurricane Fund, a state trust that offers additional risk capital to primary insurers at reduced cost because of its tax-exempt status. The state-administered residual homeowner insurance market, which became known as Citizen's Property Insurance, is a separate entity and is discussed further below.

Unravelling of catastrophe consensus-pricing

To everything there is a season (or two)

The twin North Atlantic hurricane seasons of 2004 and 2005 upset the general consensus that had emerged about how to price catastrophe risk after Hurricane Andrew. The two seasons brought record-breaking levels of damage, with nine landfalling hurricanes in 2004 and an unprecedented 16 in 2005. Four major hurricanes (Charley, Frances, Ivan and Jeanne) struck the US states of Florida and Alabama in 2004, causing roughly $57 billion in economic damages and another three (Katrina, Rita and Wilma) hit Louisiana, Mississippi and Texas in 2005, causing a staggering $148 billion in total damages (Blake et al., 2011).[33] Hurricane Katrina itself was responsible for roughly $108 billion in damages and over 1,200 fatalities, making it the most destructive natural disaster in US history (Blake et al., 2011).[34]

The effect on the (re)insurance sector in the United States was also significant. On the one hand, the models seemed to have done their job. Even though insured losses for 2004/2005 totaled a record $80 billion in 2005 dollars ($22 billion and $58 billion for each respective season), there was no string of bankruptcies, as was the case in 1992 (Guy Carpenter, 2014). In the decade after Hurricane Andrew, the arrival of event-catalogs and EP curves pushed regulators, underwriters, homeowner advocates and homebuilder associations to agree to distribute risk via higher coastal premiums, tighter building codes, hurricane deductibles, and enhanced purchasing of reinsurance

[33] A major hurricane is considered any storm between a Category 3–5 on the Saffir- Simpson hurricane scale, which means any storm with sustained winds above 111 miles per hour (178 km/h). The monetary figures do not take inflation into account.

[34] The 2017 hurricane season recently surpassed 2005 as the costliest year of natural disasters on record, with three major hurricanes and aggregated losses in excess of $300 billion. But Katrina, when adjusted for inflation, still remains the single most destructive storm in US history.

and other alternative risk transfer mechanisms (e.g. catastrophe bonds).[35] This mix of precautionary logics and logics of speculation (Ericson & Doyle, 2004a) had kept losses within expected model distributions.

On the other hand, however, the models underperformed in their estimation of something called 'demand surge' (i.e. the increase in costs of construction materials and repair work following multiple and repeated loss events in adjacent territories), and did poorly at anticipating specific kinds of property damage, missing roughly 30–60 per cent of losses in some of the coastal counties where the storms hit because of poor exposure data (Guy Carpenter, 2014). In addition to problems in the models' damage estimates, the back-to-back, record-breaking seasons sent tremors across the industry about a more basic set of questions: how variable was hurricane activity? Was this variability properly reflected in the cat models? And if not, by how much could insurers be underpricing future exposure? To top it all off, these doubts were further amplified by a growing number of scientific studies linking the effects of extreme weather to climate change.

Here come the warm jets: Climate cycles versus climate change

Cat modelers faced mounting pressure from their insurance and reinsurance clients to respond to the 2004/2005 seasons. In an analysis produced after Katrina, Munich Re, the largest reinsurance company, argued 'There is no doubt that the models used to simulate the hurricane risk in the

[35] Catastrophe bonds are part of a niche but growing financial sector called 'insurance-linked securities' (ILS) which also consumes information from cat models (Bougen, 2003). While ILS proponents laud the ability of cat bonds to expand catastrophe coverage, some analysts see them as destabilizing traditional reinsurance by taking away reinsurers' business (Jarzabkowski et al., 2015), or even worse, opening up new and exploitive avenues of disaster-based capital accumulation (Johnson, 2014). Despite the importance of ILS to questions of insuring climate risks, I bracket them here in order to stay with the cat models.

North Atlantic need adjusting' (Munich Re, 2006, p. 4). While reinsurers covered about one-third of the insured losses from 2004 (roughly what reinsurers expect in a severe year), they ended up carrying two-thirds of losses in 2005, a major over-extension of their capital reserves (Nutter, 2006).

Partly as a result of reinsurer discontent, the cat-modelling firm RMS made a decision to fundamentally change the way it analyzed and presented catastrophe risk from hurricanes (Author's interviews with RMS staff, telephone, 11 September, 2019). Rather than sticking to improvements of its standard annual estimate of hurricane risk, RMS began developing what it called a Medium-Term Rate (MTR) view of risk – a five-year, forward-looking forecast attuned to evidence that hurricane activity was, in fact, not a stationary phenomenon that could be measured through annualized historical averages. In doing so, RMS was leveraging two rival but largely complementary agendas in the scientific community of hurricane researchers – one linked to advances in knowledge about climatological cycles and the other linked to advances in knowledge about climate change.

Embracing this new knowledge would mean discarding old assumptions. For instance, use of the full HURDAT dataset was a methodological convention that had morphed into a de facto best practice in the sector since first introduced by Karen Clark in 1986. But in the early 2000s, researchers at NOAA's National Hurricane Center, the scientists responsible for managing and maintaining HURDAT, published an influential paper in the journal Science (Goldenberg et al., 2001) suggesting there was significant variability in the decadal frequency of tropical cyclones in the North Atlantic. The new research seemed to justify not using the full dataset when estimating annual loss from future hurricanes.

Their article called attention in particular to the influence of the El Niño Southern Oscillation (ENSO) and something they called the 'Atlantic multidecadal mode – now identified as the Atlantic Multi-decadal Oscillation, or AMO – on Atlantic hurricane activity.[36] Rather than occurring in a steady stream of annual events, hurricanes appeared to arrive in decadal waves, with more storms occurring between 1930s and 1960s, followed by a significant decline from the 1970s to 1990s (see *Figure 2*). 'Because these changes exhibit a multi-decadal time scale', they argued, 'the present high level of hurricane activity is likely to persist for an additional ∼10 to 40 years. The shift in climate calls for a re-evaluation of preparedness and mitigation strategies' (Goldenberg et al., 2001, p. 474, emphasis added).

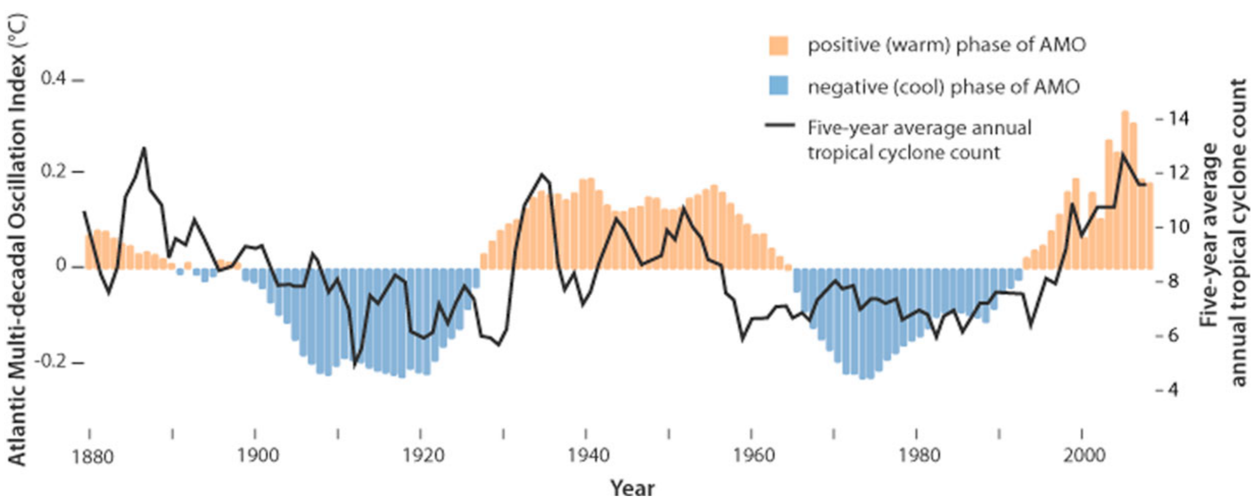

Figure 2.2. *Inter-decadal North Atlantic Hurricane Activity (1880–2010). Credit: NOAA Climate.gov graph by LuAnn Dahlman based on data courtesy of NOAA and Landsea et al. 2010.*

[36] AMO is characterized as a macro-climatological system linked to the thermohaline circulation that transfers warm waters from the Indian Ocean to the Northern Atlantic along a giant underwater 'conveyor-belt' of oceanic currents. AMO alters the sea surface temperatures of the Northern Atlantic between cooler and warmer phases. Its warmer phases appear to correspond to periods in which more hurricanes form.

In short, the National Hurricane Center's lead scientists were proposing that, in the years following Andrew, the North Atlantic was moving into a period of heightened storms. From a (re)insurer's perspective, if there was an actual fluctuation in the frequency of hurricanes on the scale of decades, then the sector was potentially heading into a stormy period with a drastic increase in loss events. While Goldenberg et al do not mention climate change in their article nor attribute any shifts in hurricane activity to climate change – indeed, none of them are climate scientists – a separate cohort of climate researchers, using much of the same data, began to analyze, and detect, a potential influence of anthropogenic climate change layered onto the 'natural' climatological cycles.

In a prophetic article published in the journal Nature just weeks before Hurricane Katrina made landfall, MIT climate scientist Kerry Emanuel argued that while there was minimal proof that climate change was driving any increase in the frequency of hurricanes, it did appear that a gradual warming of the average sea surface temperature was driving an increase in the intensity of storms. 'My results suggest that future warming may lead to an upward trend in the tropical cyclone destructive potential, and – taking into account an increasing coastal population – a substantial increase in hurricane-related losses in the twenty-first century' (Emanuel, 2005, p. 686). In a subsequent article, co-authored with noted climatologist Michael Mann, Emanuel stated the case even more bluntly: 'anthropogenic factors are likely responsible for long-term trends in tropical Atlantic warmth and tropical cyclone activity' (Mann & Emanuel, 2006, p. 233). Discounting the effects of AMO on sea surface temperatures, Mann and Emanuel explicitly linked sea-surface warming to warming trends connected to increased greenhouse gases in the atmosphere.

Eliciting the future

Citing both of these communities of scientists, RMS modelers began developing a new approach to simulating hurricanes that abandoned the use of the long-term average of hurricane activity as their 'primary-view' of risk. As they argued in a scientific publication rolling out their new model:

> The assumption of using the average of the historical record to represent the risk over the next few years holds as long as there are neither trends in activity or evidence that we are currently in an extended period of heightened or reduced activity. The record shows however that there have been prolonged periods of rates significantly different from the long-term average and a clear demonstration that we are now within one of these elevated periods. (Lonfat et al., 2007, p. 500)

The idea of elevated rates, RMS argued, sanctioned a move away from the de facto best practice of simulating synthetic events based on stochastic sampling of storm parameters from the entire HURDAT record. 'Faced with the evidence that the long-term average is no longer appropriate for assessing risk over the next few years', they summarized 'we need to explore alternative ways to assess hurricane activity' (Lonfat et al., 2007, p. 500). As their alternative, RMS proposed a forward-looking perspective of future hurricane activity, where the 'seed' data for the production of synthetic storms would favor those events found to lie within a historically similar period of climate variability (i.e. taking only the storms from 1930 to 1960).

In addition to changing how they sampled from the historical record, RMS' modelers also turned their attention to the problem of climate change. Unlike general circulation models of climate change, catastrophe models are not based on fundamental physical equations of atmospheric behavior. The computational demands of dynamically estimating phenomena like hurricane activity remains an expensive and commercially untested modelling approach (Author interviews with both AIR and RMS cat modelling engineers, telephone, 11 September, 2018 and 16 April, 2019). Including information about climate change in catastrophe risk estimations required new forms of calculation that went beyond either the statistical archival' or 'enactment' idioms of risk that the models had already creatively brought together. So, instead of building an event catalogue of synthetic storms based solely on sampling parameters from the historical record, RMS turned toward the elicitation of experts to select and weight the importance of different climatological factors in storm generation.

This elicitation process, called the 'Delphi-method', was pioneered in the 1950s by the RAND Corporation (Andersson, 2018) and uses expert judgment to compensate for a lack of empirical data in decision-making. It is frequently applied to assess risk in situations of deep uncertainty, including, infamously, estimates for which American cities were the likeliest targets of a Soviet nuclear strike (Dalkey & Helmer, 1951). While considered standard operating procedure in certain realms of military planning, corporate strategy, and even in the pricing of commercial insurance against terrorist strikes, Delphi methods were new territory for insurance-related risk assessments of extreme weather. They represented the layering of additional modes of calculation into the already complex causal logic of cat models.

Based neither on empirical data nor historical records, the elicitation consisted of asking climate experts to weight 13 different parameters that drive hurricane activity (e.g. ENSO, AMO, wind shear predictors, etc.). Iterative rounds of weighting allowed experts to adjust their rankings of which parameters they thought would be most influential in the coming five years until the processes reached 'a group consensus on the distribution of alternative interpretations' of future storm activity (Lonfat et al., 2007; Author interview with RMS cat modeler, telephone, 18 March, 2020).[37] The weightings were inserted upstream of the cat model simulation processes, modifying the Monte Carlo results by giving extra credence to specific climatological drivers of hurricane behavior.

This new calculative pluralism departed radically from the 'stochastic impartiality' that characterized the success of the initial cat models in structuring social agreement about insurance prices. Compared to the previous styles of reasoning that cat models had so artfully combined – both premised around a stationary understanding of hurricane activity – elicitation proposed a very different epistemological basis from which to simulate weather-based catastrophes. Estimates were tied explicitly to experts' professional concerns about the influence of climate change on future storms. Their convergence, as reported by RMS, was the solution that Robert Muir-Wood had hinted at in his 2005 Chicago presentation to US insurance regulators. Forecasting hurricane activity for the period between 2006 and 2010, RMS's first MTR model

[37] In the first elicitation, the four climate experts involved were Kerry Emanuel from MIT, James Elsner from Florida State University, Tom Knutson from NOAA's Geophysical Fluid Dynamics Laboratory and Mark Saunders from University College London. According to an interview with one of these participants, none of the experts understood the exact goal of the exercise until after the fact (cf., also Begos, 2007a). Extra context was also gained in an Author interview with an RMS executive involved in the elicitation 09/13/18.

estimated a 21–40 per cent increase in risk from hurricane peril for the Atlantic and Gulf Coast states (Begos, 2007a; Lonfat et al., 2007). Increased risk meant the need for increased insurance premiums, an argument with obvious appeal to insurance companies. Within the year, the other main cat modelers, AIR and EQECAT, followed with their own versions of the new Medium-Term Rate model. RMS submitted the new model to the Florida Commission on Hurricane Loss Projection Methodology (FCHLPM, see endnote 8) for validation in the summer of 2006, but it was already having a major impact on negotiations around insurance policy renewals for 2006 (St. John, 2010).[38]

Five years forward, two steps back

As insurers began submitting rates to regulators for higher insurance premiums in line with the MTR assessments, they were met with strong reactions from homeowner associations, state legislators and consumer advocates who demanded an outright rejection of the new RMS model (Begos, 2007b). Despite RMS' scientific publications and presentations about this new method (Jewson et al., 2009; Lonfat et al., 2007; NAIC, 2006) its approach brought intense scrutiny to the position of cat modelling firms in the ecosystem of homeowner insurance pricing. The Consumer Federation of America and the Center for Economic Justice, two national consumer advocate organizations expressed deep scepticism in a joint letter to the President of the National Association of Insurance Commissioners.[39] Accusing RMS of colluding with the insurance industry to raise premium rates, they called into question the status of cat modelers as

[38] Homeowner insurance is largely bought and sold on an annual basis; the seasonality of the renewal market is driven principally by the reinsurance sector, which finalizes the vast majority of catastrophe contracts on 1 January each year.
[39] The letter was also sent to all the Insurance Commissioners of the Atlantic and Gulf States, as well as the Attorney Generals of these states.

independent, third-party certifiers of risk. But they also claimed that insurers were violating their initial promises to homeowner organizations about the integrity of the models.

> This [5-year] approach is the complete opposite of that promised by insurers when these models were first introduced. Consumers were told that, after the big price increases in the wake of Hurricane Andrew, they would see price stability. This was because the projections were not based on short-term weather history, as they had been in the past, but on very long-term data from 10,000 to 100,000 years of projected experience. (Hunter & Birnbaum, 2006, p. 2)

The consumer advocates had actually helped convince regulators to adopt the cat models after Hurricane Andrew (Interview with director of consumer advocacy, telephone, 26 October, 2017) based on the principle that the 'price charged for insurance the day after a catastrophe should not change, because the events was already included in the model' (Muir-Wood, 2016, p. 143).

Their letter called forcefully for state regulators to 'reject the new RMS wind model as the basis for any rate increase and examine how this new model was developed. It is clear that the assumptions underlying the model, such as the five-year horizon, need to be fully identified and reviewed in a public forum' (Muir-Wood, 2016, p. 4, emphasis original). Consumer groups were not alone in their consternation with the Medium-Term Rate models – experts also spoke out. One of the modelling specialists reviewing the model for the Florida Commission, told reporters that RMS 'wasn't able to satisfactorily answer some questions about the model', especially concerning how the company 'used a small group of experts to justify the five-year forecast'

(Begos, 2007c). And Mark Frankel, the Director of the Science and Ethics Program at the American Association for the Advancement for Science, responding in an article in the Tampa Tribune simply asked: 'Is there any sound science to believe in this model? That seems to me very much up in the air' (Begos, 2007b).

Politicians in Florida also began mobilizing against rate increases. While Louisiana suffered the brunt of the 2005 season and its losses, it was the risk that a similar event might hit Florida that really concerned insurers. The models suggested (and continue to suggest) that a direct hit from a category 5 hurricane on Miami could see total losses of $300 billion (in 2017 dollars) and insured losses upwards of $180 billion (Swiss Re, 2017). Such an event could cripple the entire sector and thrust the state's real-estate-based economy into a downward spiral (Weinkle, 2015). RMS' MTR model increased the odds on this kind of event happening in the next five years, but Florida politicians refused to allow yet another round of major premium hikes on homeowner policies (Ubert, 2017).

RMS, meanwhile, argued that its new models were correcting an actuarially unsound pool of risk and protecting the general taxpayer from footing future disaster bills for under-insured coastal property owners (NAIC, 2006). As Hemant Shah, the CEO of RMS, told the Sarasota, FL-based Herald-Tribune, 'How are you going to incent people to mitigate their homes if you don't have the right kind of signaling on what risk really is?' (St. John, 2010). Expert elicitation, from RMS' perspective, was a critical tool for governing and distributing the meteorological uncertainties of climate-fueled catastrophes.

While these battles played out in the press and public forums, insurers had to wait for approval from the Florida Commission before they could actually use the MTR model to set homeowner premiums. But other (re)insurance actors, not subject to state regulation, were rapidly incorporating the five-year perspective into their risk assessments, putting a squeeze on primary insurers. Both reinsurers and rating agencies hardened their views on underwriting in the region (Guy Carpenter, 2014; Munich Re, 2006). By applying RMS' MTR model, Moody's, S&P's and AM Best determined that insurers across the southern Atlantic states, but particularly in Florida, were facing an $82 billion shortfall in their capacity to cover the increased loss estimates of the MTR model (St. John, 2010). The negative assessment of capital adequacy put extra pressure on insurers from their investors to increase premiums or risk reductions in their stock price.

The dynamics of insurance regulation made finding common ground between the insurers and coastal state officials extremely difficult, with shareholders pressing for higher rates and citizens endorsing political candidates who were guaranteeing no significant price hikes. As a result, many insurance firms opted to reduce coverage across the entire region. To slow the exodus, Florida state legislators passed a series of tough exit laws, but they also moved to protect homeowners from losing their insurance by expanding what was known as the 'residual' market, a state-run insurance fund called Citizens Property (Ubert, 2017). Intended as an insurance scheme of last resort, Citizens quickly ballooned from representing a 'residual' pool of homeowner risk to become the largest insurer of residential property in the state (Weinkle, 2015).[40]

[40] The changes to the Florida insurance markets following 2004/2005 are a connected but separate story to the innovations in cat modelling. They are covered extensively in Ubert (2017), Weinkle (2015) and Johnson (2011) (particularly chapter 6). Since Citizens was capped from increasing premiums beyond a specific percentage per year (currently 10 per cent), it effectively subsidized prices for coastal properties even those that might otherwise afford

If Florida played a particularly visible role in how this overall dynamic played out, it was far from alone. Nearly every Gulf and Atlantic coastal state was affected by the MTR model changes, and almost all took cues from the Florida model review commission on whether or not to approve the use of the new models in ratemaking. After a series of unfavorable presentations to the commission, RMS withdrew the MTR model from the validation process in 2007 (Begos, 2007c; Author interview with FLOIR staff, telephone, 18 July, 2019). This did not stop many states from eventually passing their own pre-emptory bans of the new assessment techniques. South Carolina's Department of Insurance 2014 law on 'The Use of Hurricane Models in Property Insurance Ratemaking' is exemplary. It specifies that the Department does not 'permit the use of any of the following model variations: 'short-term', 'near-term', 'medium-term', 'warm-phase', 'warm-water', 'warm sea surface temperature', or any other variation that, although different in the title than the aforementioned examples, has a similar effect of limiting the modelled period. Only the long-term variation of catastrophe models is permitted' (South Carolina DOI, 2014, p. 3).

What had been an informal best practice based on the combination of two risk idioms – 'simulated' event catalogues based on the full 'archival' record of hurricanes – became a regulated standard. Previously an implicit norm, 'stochastic impartiality' was codified as part of the models' legal status. It was now an official source of their legitimacy.

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actuarily prudent insurance. Its solvency is 'guaranteed' by a legislatively granted authority to levy a premium increase on all rate payers across the state should a disaster strike and Citizens' surplus prove inadequate to pay its claims. The political and financial consequences of this guarantee have not been tested.

Reclassification and retreat

Despite withdrawing from the Florida hurricane commission review in 2007, RMS continued to conduct annual elicitations through 2008 and promote the MTR to clients as its ‘primary-view’ of risk. Other cat modelers shifted tactics earlier on. According to a team of AIR scientists, the medium-term rate models, what they called their ‘near-term model’, depended on too many leaps of causality to justify its use in rate setting; each additional leap ‘introduced too much uncertainty into the determination of hurricane activity’ (Dailey et al., 2009). In their own publication in the peer-reviewed Journal of Applied Meteorology and Climatology, the AIR team argued that even if the warmer sea surface temperatures identified as a phase of the AMO is a good proxy of hurricane activity, warmer temperatures alone do not indicate more land-falling hurricanes because of other intervening climate patterns, including El Ni o and a differential pressure system called the Bermuda High, among other factors. Each step of logic in the five-year perspective, beginning especially with the explicit deployment of human judgment, presented additional challenges to translating risk estimations into the idiom of statistical probability that was the cornerstone of the models’ initial success.

As their technical problems mounted, AIR modelers pivoted in 2007 and, rather than offering a five-year forward-looking model, introduced what they call their ‘warm sea surface temperature’ (WSST) catalogue. They make no claims about capturing any data regarding climate change in their model, but emphasize the correlation between the conditions of warming sea surfaces in the Atlantic Basin and increased hurricane intensity. They sell the model as a ‘supplemental’ view of risk, rather than their ‘primary’ view. In other words, where cat modelers initially emerged after Hurricane Andrew as guarantors of a ‘stochastically impartial’ view of catastrophic risk, they were now offering a proliferation of risk perspectives, asking their different audiences to pick and choose from multiple assessment offerings.

Of all the actors in the insurance constellation, this move toward multimodal modelling was perhaps most favourable to (re)insurance brokers. It increased their value as agents who can help their clients 'own their view of risk', by 'blending', 'morphing' and 'fusing' outputs from multiple models into bespoke views of risk (Guy Carpenter, 2014; Major, 2013). But the move toward climate conditioned catalogues also heralded the end of a particular logic in cat modelling, where the occurrence of natural disasters, despite their randomness, were nonetheless characterized by an underlying 'stationarity'.

Perhaps the most significant challenge, however, to the Medium-Term perspective came from the hurricanes themselves. Instead of cooperating with the dire expectations of increased damages, storm activity shifted drastically across the entire basin. There was not a single major landfalling hurricane for the entire period between 2006 and 2010.[41][23] The scholar Robert Pielke Jr. (who also served as an expert in one of RMS' latter elicitations) wrote a harsh commentary comparing the 'skillfullness' of the MTR models in forecasting future hurricane seasons as roughly similar to that of a 'room full of monkeys' (Pielke, 2009). Whether or not such derision was deserved, until the recently devastating 2017 season, the southern Atlantic coast of the United States experienced a roughly 13-year 'drought' of major hurricanes – the longest such period in NOAA's historical record.

[41] The year 2010 actually saw a very high number of hurricanes and tropical storms (19), just none of them made landfall in the United States. The 2011 and 2012 seasons continued in the same vein, while most storms remained relatively weak in strength, two hurricanes struck the United States (Irene in 2011 and Sandy in 2012), although neither hit the Gulf coast.

Already facing strong headwinds of doubt, compounded by problematic updates in 2011 to its inland wind field simulations (Willis Re, 2012), RMS quietly reverted to the long-term historical view of risk for many of its key services and clients. The company continues to offer the MTR perspective (like AIR), but its current efforts have focused on reanalysis and bootstrapping of the decadal cyclone and sea-surface temperature data sets, rather than actually dealing with questions of climate change (Bonazzi et al., 2014; Caron et al., 2018). Despite cat modelers efforts to push damage estimates into a world where the statistical analysis of hurricanes is decoupled from their past behaviour, dissent from homeowner advocates, regulators, politicians, and eventually the storms themselves, created a broader loss of consensus with climate-enhanced cat models.

Multiplying perspectives of risk

This paper examines how expert understandings of peril from severe tropical storms in the North Atlantic shifted away from a 'stationary-view' toward a 'non-stationary view' of weather-related risk. The effort to embrace non-stationarity in risk estimates caused one of the principal cat modelling firms, Risk Management Solutions, to dramatically alter the way it projected future hurricane losses, and thus how insurers, reinsurers, rating agencies and regulators negotiated the value of insurance premiums. The shift in expert perception was driven largely by the unprecedentedness of the 2004/2005 hurricane seasons and engagement by the (re)insurance sector with a broader scientific debate about the influence of climate cycles and climate change on the underlying stochastic nature of extreme weather. If cat models initially served to create consensus about how to price the risk to property from rare events, the resulting model revisions pursued by RMS after 2005 triggered new disputes about the acceptable role of expertise in determining the affordability of insurance. RMS's initial approach to the problem of non-stationarity was to combine new empirical sampling techniques based on climate variability with expert elicitation in the selection of models believed to be most predictive of the coming five-years of storm conditions. The former technique addressed the influence of natural climate cycles on hurricane formation (such as the Atlantic Multidecadal Oscillation) whereas the latter targeted expert understandings of the influences of climate change. The overall impact was an increase in the model's disaster loss estimates from hurricanes by 21–40 per cent across the Atlantic and Gulf coasts compared to the long-term, stationary view (Lonfat et al., 2007).

In mixing statistical, simulative and subjective 'styles of reasoning' – three different idioms of risk identification – RMS was, in some ways, merely extending the combinatorial approach that made the models a success in the first place. Delphi-style assessment techniques, however, proved one bridge too far for stakeholders in the field of homeowner insurance to cross. Although widely used in areas of strategic planning, as well as by cat modelers in assessing commercial insurance for terrorist attacks and nuclear accidents, expert elicitation is generally at odds with the kind of trust in numbers' that has arisen in the more actuarially strict world of homeowner pricing. Its inclusion in the simulated environment of hurricane models introduced a troubling element of epistemological hybridity that threatened the status of the models, revealing the frontiers of translatability between different idioms of risk.

Yet even when elicitation was finally renounced, selective sampling of the HURDAT record continued to upset previous political agreements of how to assess hurricane risk based on 'stochastic impartiality', prompting coastal states to officially exclude new modelling techniques from ratemaking. Rather than promoting a single view of hazard risk, modelers now offer multiple visions of risk (a primary and a supplemental), with multiple time horizons (one to five years). The multiplication of risk perspectives means that adversely situated actors can calibrate the perspective that best corresponds to their position and interests within the constellation of insurance-related actors: capital markets, reinsurers and rating agencies prefer more conservative models; regulators, consumer advocates and legislators prefer models that prevent price hikes on their constituents; and insurers, caught between a rock and a hard place, try to navigate between the two.

The net result is that model outputs now require more interpretive work from their clients and create even less of a shared scientific basis for agreement about prices then they did in the past (Weinkle & Pielke, 2017). While MTR, WSST and other models are not directly allowed into ratemaking for homeowner premiums, they still have a significant impact on insurance prices since reinsurers and capital markets use them to assess the cost of reinsurance, a cost that is passed back along to customers. In the coastal markets of Florida, Louisiana and Texas the reinsurance portion of the premium (which covers catastrophe risk), can be upwards of one-third of the entire premium (Gilway, 2017; Interview with Head actuary of Gulf state department of insurance, telephone, 16 September, 2019).

One of the most remarkable developments since 2005, however, is that despite the selective use of these models in certain corners of (re)insurance, premium prices have not spiked as many feared. The decades long absence of major disasters, and the entrance of alternative risk transfer capital (enabled by the models) have contributed to keeping coastal (re)insurance prices lower than predicted when the alternative models were first released. Beginning in 2017, a new spate of devastating storms have since hit the US, but it remains to be seen how these storms will impact risk assessment practices going forward. By denying direct use of the Medium-Term models in ratemaking and extending subsidized forms of public insurance, coastal state regulators seem, for the moment at least, to be intent on shoring up the existing system of risk distribution. In doing so, they are also dodging a fuller accounting of how to address the ongoing and worsening impacts of climate change in their regions, particularly regarding how the inexorable creep of sea level rise will complexify (and potentially render moot) the question of windstorm underwriting along the coasts.

As of this writing, many questions remain about the relationships between climate variability and climate change on hurricane formation. A growing body of sciences points out that the frequency of North Atlantic hurricanes might actually decrease (due to countervailing effects of simultaneous warmer sea surface temperatures in the Indo-Pacific, which promotes wind shear), but become more intense, move more slowly overland and produce more rain (Kossin et al., 2020; Sobel et al., 2016; Trenberth et al., 2018). One thing is certain, however, and that is that the issue of non-stationarity is not going away. And it is not a matter isolated just to hurricane risks, nor just to US Gulf states. Similar dynamics are already at play for other perils such as fire, drought, heatwaves and rain-induced flooding around the globe. The assessment of hurricane risk analyzed here serves as a bellwether of the political disputes about the extent to which climate-influenced risks should be assessed as problems of individual property-holders and framed in the context of insurance, or require a new social compact of risk sharing. Pressure will continue to build on developing loss-estimate tools that can account for a dynamic, non-stationary world of weather, but new techniques will not foreclose the deeper questions of how to fairly distribute the escalating economic burdens of a changing climate.

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Chapter 3

Cultures of Anticipation: Material practices, public authority, and governing water scarcity in the Southwest of France

Yves Daros leans back in his office chair and scratches his mustache: “In this part of France,” he tells me, “We have a tradition of polyculture agriculture. The farms aren’t very big, no more than sixty hectares on average, which is just enough to support a family.” We are sitting in the office of his farmhouse, perched on a wooded hill near the village of Peyrole, a rural community of about 700 people located in the southwest French *départment* of the Tarn. Outside, the countryside spills east, alternating between planted fields, small agglomerations of homes and stretches of forest. I’ve come here to ask Daros about his farming practices, and he answers my questions in a quiet but deliberate voice, clasping both hands in front of him as he talks.

Figure 3.1. *Yves Daros at his home office on his farm in Peyrole, Tarn.*

His grandfather, who bought the farm after World War II, planted vegetables, raised milk cows, and even grew grapes for wine, “But now,” he tells me, “if you don’t specialize you won’t survive.” The fields in front of his house are planted with a mix of cereal crops – winter wheat, canola, corn, soy, and sunflower. Daros rotates the fields between winter seed and spring crops, leaving them fallow every third of fourth year. The rotation gives the soils a rest, but also helps control pests. In the mid 1970s, in an effort to diversify the farm’s revenue sources, he and his father started raising pigs. Grain from the farm became animal feed, while manure from the pigs returned to his fields as fertilizer for his crops. He now has about 900 head of pork, which are kept in a nearby livestock cooperative and destined for butcher shops and grocery store delis all around France.

When Daros and his father decided to convert their fields to grow feed for their animals, they knew they would need a steady supply of water for irrigation. Crops such as wheat or canola do well in dry conditions; but cereals with higher caloric value, such as sunflower, soy and corn – crops that make good animal feed – need a lot of water. “And even more so here because of the region’s complicated climatology”, Daros tells me. “The continental climate is very dry in the summer, and very wet in the winter. The summer we can go two or three months without a single drop of rain. So, we have to secure water for our crops.”

As a first step toward achieving water security, he and his father installed a small *lac collinaire* on the farm*,* a hillside retaining pond, to collect runoff from the winter rains (see *Figure 3.2*). These small retention ponds dot the country side, but typically hold enough water for only one or two rounds of irrigation at best. In a really dry year, DaRos knew they might need as much as nine to ten rounds of irrigation per field of corn. Although the Tarn, a tributary of the larger Garonne River (from which the river basin takes its name), is only a few kilometers away, the topography made it impossible for them to withdraw water directly from the river. So, in the mid-1980s, Daros and his father organized a group of local farmers to create an *Association Syndicale Autorisée*, or ASA, a rural irrigation cooperative. Each farmer borrowed some money from local banks (a "colossal sum at the time", as Daros recalls), and along with some financing from the regional government, bought a nearby farm that was up for sale, built a dam across a small stream called the Badaillac, and flooded the land to create a 1,500,000 m3 irrigation reservoir.

Figure 3.2. The photo on the left shows Daros' lac collinaire, built on his property in 1976 (holding about 15,000 m^3 of water; in the distance of the photo on the right, we can see the collective reservoir of Peyrole, built in 1989, holding roughly a thousand times more water.

From his porch, we can just make out the reservoir in the distance, a thick band of blue shimmering between stands of oak trees. The reservoir feeds a subterranean network of irrigation pipes that snake their way under the landscape, providing water, and the means to make a living, to thirty-five neighboring farms. Since the *ASA de Peyrole* built its dam, its members have gained a sort of freedom from the annual anxieties that plague other farmers in the region who do not have a guaranteed supply of water. Meanwhile, farmers without access to their own reservoirs pump directly from the region's rivers and streams.[42] These farmers pay for this "water right", yet in years with little rainfall, when the stream-levels in the watershed fall below a fixed threshold, the government begins restricting water use in order to protect both human health and aquatic life.[43]

Despite their water concessions, farmers are first in line to face restrictions. When this happens, the impacts are fairly self-explanatory: "Without water," as Daros exclaims, "we don't have any crops!" From the farmer's perspective, the straightforward solution to this problem is to increase the number and capacity of the region's reservoirs. Over the past thirty years, however, it has become very difficult to do what Daros and his father did because of a "social conflict around water", as Daros it. "On one side," he tells me, "are the farmers who need water to be sure that what they plant in the Spring, they will be able to harvest in the Fall. On the other side are the environmental groups, who want us to leave nature entirely to itself."

Whether or not the conflicts can be reduced to binary positions of for/against farming, or for/against the environment, Daros' perception of "two camps" is historically grounded in a particularly contentious infrastructure project – the Charlas Dam. Proposed in the late 1980s as a

[42] Unlike places such as the United States, deep, groundwater aquifer pumping is banned in France, so farmers must make do with "surface waters" i.e. the aquifer that is in direct communication with the region's rivers and streams.
[43] The legal framework governing water use in France is set by the European Framework Directive on Water (2000), codified by the French state under its 2006 Law on Water and Aquatic Environments. The Framework Directive requires all rivers and streams to meet certain standards of water quality within certain timeframes. Rivers absorb and transport many forms of anthropogenic pollutants – toxic industrial waste, chemicals from pharmaceuticals products such as anti-depressants or birth control pills, and agricultural runoff in the form of excess nitrogen, phosphorous and various pesticides and herbicides). To ensure these pollutants are diluted to environmentally "safe" concentrations, regulators seek to maintain specific flow volumes in the rivers they manage. Managing the quantity of water helps ensure its quality. Water levels in the rivers of the Garonne, and elsewhere in France, are thus pegged to certain thresholds in order to guarantee that the concentration of pollutants is diluted to an epidemiological standard considered "safe" for the health of humans and other riverine species of life.

means to solve farmers' perennial problems of water shortage, the plan was to create a massive 110 million m3 reservoir on the upper portions of the Garonne River (flooding the village of Charlas and the agricultural lands of roughly thirty farming families in the process). A reservoir of this size would introduce "slack" into the system, as dam advocates argued, creating a buffer for those moments of the year when water was particularly scarce (Thepot 1997). Despite support from the central French state, however, the project incited fierce opposition by local environmental groups who eventually succeeded in scuttling the deal in 2003 because of its ballooning cost and significant environmental impacts.[44]

In the absence of an infrastructural solution to their perennial problem of water scarcity, and constrained by laws governing water quality, farmers have been forced to adapt how they use water. For the most part, this has meant improving their "water efficiency", i.e. doing more with less. This has included adopting new techniques of precision irrigation, soil monitoring, and developing improved versions of *lac collinaires* that do not directly obstruct streams and other small waterways. These new material practices, along with an administrative reform of existing water rights, have worked to reduce irrigation related water use in the region. All, nonetheless, while maintaining the existing political economy of export-oriented, input-intensive agriculture.

When I visited the Garonne between 2013-2015, however, a new problem was emerging that was upsetting previous long-standing assumptions about local water management.[45] A study had just

[44] A version of Charlas existed on the drawing boards of different groups since at least the 1960s, but a concerted push to get the project built really began in the mid 1980s. Sara Fernandez has written a dissertation that covers this extensive history (Fernandez 2009).
[45] This chapter is based on three years of fieldwork in the "watershed region of the Garonne River", which I often reduce to the simple shorthand of "the Garonne" to imply the region. This fieldwork included attending dozens of public meetings (some closed to the general public, but to which I was granted access) and forums organized by the Adour-Garonne Water Agency, the Watershed Committee of the Water Agency, the Syndicat Mixte d'Etude et

been released by the Adour-Garonne Water Agency (AGWA), the public entity responsible for overseeing regional water use. Called *Garonne 2050,* the study looked at future conditions of the watershed under different scenarios of climate change "with the aim of anticipating future struggles and proposing a strategy of adaptation" (AGWA 2014: 4). The results were grim: scientists expected major reductions in water availability during the crucial summer months when economic and social demands on the watershed are at their greatest. According to the study, the region would be facing between twenty to forty percent less water during this period by 2050.[46]

For the different groups I spoke with involved in the region's water politics, including farmers, hydroelectricity operators, gravel miners, kayakers, fishing groups, environmental organizations, landscape architects, urban officials, and locally elected representatives, these numbers presented a troubling vision of future resource scarcity. Any significant changes to water availability would potentially unravel the tenuous political agreements surrounding existing social uses of water. These agreements are codified in the Water Agency's *Schema Directive de l'Amenagement et*

Amenagement de la Garonne where water governance and planning measures were discussed and sometimes voted upon. I also engaged in participant observation of different actors in their daily interactions with water as 1) part of their livelihood (farmers, agricultural service providers, hydroelectric plant operators), 2) as part of their functions as members of state bureaucracies responsible for monitoring and maintaining the environmental health of the region's rivers (ONEMA, DREAL, Université de Toulouse), 3) as part of their advocacy work to protect or restore nature (nature conservation groups and landscape architects) or 4) recreate in the rivers (kayakers and fishing organizations). These moments of observation, which varied between roughly one to four were conducted over a wide swathe of the watershed and consisted largely of "tagging along" with individuals from these different groups on prescheduled activities, such as fish surveys, river bank restoration work, maintenance of irrigation systems, or corn planting. In tandem with these visits, I also conducted 48 semi-structured interviews with actors from many of the groups listed above.

[46] The SDAGE 2016-2021 quotes Garonne 2050, Imagine 30 and Explore 2070 to provide the figure of 20-40% lowering of the average *étiage* by 2050 (Comité du Basin 2015, 29). In the Synthesis of Garonne 2050, however, it communicates the results of these studies differently, suggesting the population might experience up to a 50% reduction of the debit d'étiage by 2050 in a bad year: "*à l'horizon 2050, même si les incertitudes demeurent importantes pour les précipitations, l'élévation de la température entraînera une augmentation forte de l'évapotranspiration. Les débits naturels d'étiage seront en moyenne réduits de moitié pour le bassin de la Garonne*" (Ibid., 4). The 20-40% figure reflects the range of gradual change expected from 2015 to 2050, rather than the abrupt shift in the year 2050, which is why I choose to highlight the range rather than the fifty percent figure.

Gestion des Eaux (SDAGE), a Master Plan for regional water use that is revisited every five years and approved by a delegated body of water stakeholders called the Watershed Committee (Yves Daros is a member). During my fieldwork, the Watershed Committee was in the process of writing a new Master Plan taking into account the conclusions from *Garonne 2050*. "In weighing the risks posed [to the region] by climate change," the final text stated, "the SDAGE for the period of 2016-2021 must promote long-term thinking and a culture of anticipation" (Comité du Basin 2015, 28).

Following a widespread campaign of public engagement about the results of *Garonne 2050*, most of the actors I spoke with all seemed to take the problem of climate change seriously. So, picking up on the felicitous phrase used by the Watershed Committee, this chapter attempts to make sense of this emerging "culture of anticipation".[47] Yet, since peoples' use of water is not the same, climate change will not affect everyone in the same way. As one of my informants told me, while "there is a relative consensus [in the region] about the fact that we need to adapt, in reality, no one is talking about the same kind of adaptation" (Interview w/Denis Salles). What then does a "culture of anticipation" mean in the context of divergent and sometimes competing human relationships to water? How does a general awareness of change translate into the existing politics of resource management? And what are the consequences of different forms of anticipation in terms of creating support for specific adaptative solutions to a situation of increasing water scarcity?

[47] There is a nice double entendre in French with "culture", which means both "culture" and "crops". So, we can also understand a "*culture of anticipation*" to include "anticipatory crop(s)", i.e. crops that somehow participate in a process of adaptation.

This chapter explores these questions by focusing on a key group in the network of local water users: the intensive, commodity-producing farming communities of the Garonne. I examine how this class of farmers, by far the largest form of agriculture practiced in the watershed, come to articulate the problem of climate change in light of their economic dependencies on water.[48] I argue that the concept of anticipation provides an analytical key for understanding how actors both adjust to and mobilize the problem of climate change as a means for securing future access to important resources. On the one hand, farmers "anticipate" a future where water will be scarcer by adopting new farming techniques that reduce, in very material ways, the amount of water needed for growing their crops. On the other hand, these material practices also serve to "anticipate" calls from environmentalist opponents for even deeper cuts to irrigation in the future. The suite of material practices that produce more efficient use of water in the region also participate in producing a semiotics of sacrifice and adjustment that help forestall more transformative calls for change. By pointing to their own efforts at saving water, the farmers take the political wind out of the regulatory sails of environmentalists seeking further agricultural restrictions. At the same time, they turn the idea of creating more artificial reservoirs into a reasonable, even necessary, means of adapting to a changing climate.

The chapter proceeds by first engaging with theoretical work on the concept of anticipation as a way to help situate the fairly ambiguous call by the Water Committee for the creation of a "culture of anticipation". I then return to the Garonne and introduce recent concerns about

[48] The farming community in Southwest France is far from homogenous. There are many types of crops grown and many labels for the ways crops are cultivated, from intensive methods of farming to organic, biodynamic, unconventional, and no-till agriculture. In this chapter, I focus on the region's dominant form of agriculture, which are semi-industrialized farming operations that use some quantities of fertilizer, herbicides and pesticides with regularity and whose sales are oriented toward global commodity markets.

climate change within a longer genealogy of regional water governance. The next section elaborates through empirical material how mainstream farming culture has worked across various spatial and temporal scales to integrate ecological arguments about water efficiency into their farming techniques and political claims. I turn then briefly to examine the paradoxical ways that increased efficiency of resources use does not necessarily lead to reduced use of resources. Finally, I conclude by analyzing how material forms of "anticipation" adopted by farmers both change their farming practices while also justify arguments that adapting to climate-induced water scarcity will require building more artificial reservoirs. By merging concerns from political sociology about the distributional impacts of stakeholder-driven public policy with STS approaches to material culture this chapter contributes to enlarging understandings of how material practices oriented toward collective future problems can upend previous field-level constraints to particular stakeholder projects.

Anticipation and its material effects

Social science interest in anticipation, and "anticipatory knowledge", stretches back to at least the beginning of World War II and the articulation of cybernetics thinking by figures such as Norbert Weiner and the emergence of operations research and systems engineering (Heims 1993; Fortun and Schweber 1993). As STS scholar Bronislaw Szerszynski emphasizes, anticipation itself can be thought of as a "form of causation in which the present behavior of entities and systems…is shaped by future events" (Szerszynski 2015: 1). The creation of nuclear devices (both reactors and bombs) and the risks they posed to the national security of the United States, the Soviet Union and various European powers led to the development of a whole suite of techniques such as scenario planning, forecasting, and computer simulation intended to enhance the ability of these countries to act strategically despite the deep uncertainties posed by such rare put potentially devastating future events (Andersson 2018; Rindzevičiūtė 2016).

The widespread diffusion of anticipatory tools spurred the growth of an entire industry of prognosticators and futurologists whose expertise continues to influence how administrative actors, corporations, and other organizations perceive and attempt to proactively shape indeterminate futures to their advantage (Jouvenal 1967; Meadows 1972; Bell 1973; Turner 2010). Beginning in the 1990s, a wave of social scientists linked to the sociology of risk, geography, and science and technology studies (STS), began looking more closely at the social and political effects of these tools. This early critical literature was particularly attentive to processes of planning and decision making that occurred around large scale, catastrophic events, such as nuclear fallout, industrially contaminated food systems, laboratory triggered pandemics, terrorism, and climate change enhanced natural disasters for which many of these tools were initially designed (Beck 1992; Luhmann 1993; Bougen 2004; Ericson and Doyle 2004; Lakoff 2007; Collier and Lakoff 2008; Collier 2008).

Much of this critical scholarship has worked to clarify how anticipation operates: What are the expert practices that create and sustain credible information about the future? How is this information disseminated? And how does it gain salience in present actors' contemporary projects of governance or control (Aykut et al 2019)? In an attempt to categorize these trajectories, geographer Ben Anderson (2010) identifies what he calls logics of "anticipatory action". These "logics involve action that aims to prevent, mitigate, adapt to, prepare for, or preempt specific futures" (Ibid, 779). Adaptation to climate change, as a problem, fits what Anderson calls the logic preparedness, a form of anticipating "bad surprises" in the future by protecting against them in the present. Preparedness, however, does not imply equal protection for all. "Anticipatory action will only provide relief, or promise to provide relief," as Anderson argues, "to a valued life, not necessarily all life" (780). Making sure your way of life is "counted" as valuable is thus a political imperative for any social group involved in anticipatory actions, including adaptation planning.

While the Water Committee of the Adour Garonne invokes a "culture of anticipation" as a kind of collective mindset, articulating this *in vivo* category with theoretical work on anticipation helps sharpen how this culture manifests itself within processes of climate adaptation happening in the Garonne. Toward that aim, I also draw on research into anticipation coming from the field of cultural sociology. This body of scholarship is interested in anticipation as a category of shared social experience, and the ways in which "modes of anticipation" help coordinate collective social futures (Tavory and Eliasoph 2013; Mische 2009; Wagner-Pacifici 2009). Anticipation is constantly occurring in daily life, from the efforts of individuals to sustain ephemeral, face-to-face interactions, to peoples' pursuits of personal projects, to expectations about the flow of events bound up in the temporal structures of modern life, such as the rhythms of industrial capitalism (investment cycles; weekend leisure time) and the nation-state (school calendars; election campaigns). As Tavory and Eliasoph suggest, these different scales of anticipation interact with each other, generating consequences for peoples' sense of their own ability to influence their, and their communities', destinies. Considering anticipation as a category of shared social experience, these scholars have pointed out how stories and other discursive tools play an integral role in shaping collective futures (Polleta 2009; Mische 2014, Beckert 2016). The imagining of specific outcomes for specific groups of people, in other words, helps both frame, interpret, and mobilize political action in the here and now. Shared stories about a desired future, in other words, can help people make sense of, and justify, behavior in the present (Polleta et al 2011).

This paper combines elements of both of these approaches to anticipation, but with slight modifications and extensions. In contrast to the critical literature on anticipation, we are not looking at expert cultures of future-making in this chapter. Rather than focus on the epistemic networks, technical platforms, and social institutions within which forecasts are produced, compared and interpreted – what Paul Edwards calls the "infrastructures of anticipation" (Edwards 2010) – I pay attention to more quotidian forms of anticipatory culture. Granting some level of stability to the anticipatory knowledge of the experts (that they have been taken seriously by other actors), allows us to look at how this knowledge is distributed "downstream" into the practices of other social actors.[49] Additionally, whereas much of the earlier work on anticipation focused on the consequences of extreme shocks, our case is predicated more on gradual change. The political challenge of governing water in the Garonne River basin of the future is about managing a trend line that, while punctuated by moments of severity, is characterized by an incremental but creeping mismatch between available water and the momentary demand for water at specific conjunctures of the year.

[49] Of course, "stabilizing" the anticipatory knowledge of the climate modelers, hydrologists and other experts involved in a study such as the Water Agency's study *Garonne 2050* is like pinning a live butterfly to a collector's board; not only is it subject to further motion and movement, but it is also liable to be influenced by the activities of the actors that it claims itself to analyze at distance (i.e. the various water users in the Garonne river basin). Nonetheless, even this partial knowledge has its effects, and it is those that we are hoping to center in our chapter.

Rivers are good sites to analyze how anticipation gets grounded in the daily interaction of humans with their environment. Often heavily modified (through dikes, dams, levees, bridges, canals, and irrigation projects), rivers are perhaps better thought of as co-produced, socio-material systems, or what environmental historian Richard White calls "organic machines". Rivers are "enacted" (Law and Urry 2004) through human and non-human interactions. Just as there are multiple ways of "doing" forests (Tsing 2015), or disease (Mol 2002), there are multiple ways of doing rivers. And while making a cultural point out of anticipation, as the Water Committee does, appears to both pluralize and depoliticize anticipation – it can be many things to many people – these multiple doings often collide, creating tensions and conflict.

One consequence of preparing for a future river with less water has meant equipping the watershed with an increasing array of instruments and measuring devices, from water meters to soil surveillance systems to flow-rate stations, that provide a constant flow of information about the status of the river. The expansion of these tools help planners better understand (and model) the interaction of humans and the environment, and the environment and the climate. As many scholars in STS have pointed out, information gathering at scale often produces novel, unintended sources of knowledge (Latour 1986; Akrich 1997; Zuboff 2015). Water meters, for instance do not just report on the comportment of disaggregated individual farmers; they also frame those disaggregated individuals as a "collective", generating new insights into collective level behavior (von Schnitzler 2008). The farmers in the Garonne do not escape this process of framing, but since the functioning of the technology requires their participation, it also creates openings for representatives of this group to advance their own anticipatory modes of adaptation.

By showing that they are “doing their part” to reduce withdrawals from the river system, farmers perform a kind of semiotics of efficiency that aligns with regional adaptation efforts. This semiotics, by which I mean the process by which meaning is built through technical objects (cf Akrich and Latour 1997, p259), is made manifest by how these material practices are folded into a larger story of farmers as generally willing to compromise and even sacrifice for the greater good. This semiotics of sacrifice signals an awareness of environmental constraints, while at the same time strengthening the farming community’s arguments about how climate adaptation must also involve constructing new dams in the parts of the watershed with persistent problems of water penury. Cultures of anticipation, in other words, are sets of practices, discourses, and activities that appear responsive to the forecasts emerging from the expert tools of anticipatory knowledge, while also advancing frames and stories that value (and thus seek to protect) specific ways of life.

Governing structural deficits

The Garonne River is the main waterway in the Southwest of France. With its headwaters beginning in the summits of the Spanish Pyrenees, the river tumbles north and east through the foothills of the *Pays de Comminges*, before gradually snaking northwest around the old Occitane city of Toulouse, slowing its trajectory through flat valley land where its waters are joined by the rivers of the Tarn, Lot, and Dordogne, before exiting in the estuary of the Gironde, near the city of Bordeaux. The overall watershed, named after the Garonne, occupies roughly one sixth of the France’s national territory (see *Figure 3.3*).

Figure 3.3. *Map of Garonne and Adour River Watersheds. Credit: Pauline Gourlet and the MEDEA Project, Sciences Po médialab*

In France, the distribution and allocation of water is managed at the geographic level of major river basins. This includes water for urban drinking and waste, as well as water for agriculture, industrial uses, recreation and for what the French call the *milieu*, which translates roughly to the English concept of the environment, but implies something slightly different.[50] There are no private water rights in France, rather the central state, "owns" the water, providing concessions for particular uses. This juridical system, largely unchanged from the *ancien regime* to the First Republic, was not really coupled with rational management at the territorial level until the 1960s,

[50] The English word environment is also derived from a French word, *environ*, or "surroundings". *Milieu*, translated literally means the "middle", the "from the middle of the place", and connotes something closer to "the space that is made of life". Isabelle Stengers, the Belgian philosopher has used this word play to propose thinking about the environment as '*penser par le milieu*' or 'thinking from the middle' (Stengers 2003).

when the French state created Water Agencies for the country's six principal river basins.[51] Even after the 1960s, rationalizing water management often meant accommodating current local uses, while also enlisting water in national projects of economic growth (Trottier and Fernandez 2010).

From a hydrological point of view, the Garonne watershed experiences more variability (both inter-seasonal and annual) in available surface water than any of France's other river systems. This is because the snows in the Pyrenees, which provide significant reserves of meltwater, are fickle in terms of when they arrive and when they vanish. Historically, this variability created problems largely for activities of transport along the river, but as water use increased after World War II, different user groups became interested in making water availability more predictable. So, they began creating retaining structures to stock large volumes of water, both for hydroelectricity production and irrigation. This infrastructural expansion, common across French rivers at the time, took on an added justification in the Garonne as the only way to combat what became known among administrative and economic actors in the region as the river's "structural deficit" in water.[52]

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[51] These include the Loire, Rhone, Seine, Adour-Garonne, Meuse-Rhine, and the Artois in Picardie. These basins are defined by a central riverway that eventually meets the sea. The Adour River is a small river that does not connect to the Garonne, but drains the landscapes around the Pyrenees towns of Pau, Tarbes, and Dax, emptying in the French Basque town of Bayonne (see *Figure 3.3*).

[52] In a comprehensive study of twentieth century water governance on the Garonne, STS scholar Sara Fernandez argues that this concept of "structural deficit" circulated from one era of water use to the next. In the late 19th century, barge traffic was plagued by moments when water levels dropped too low to carry the river freight, compelling the dredging and construction of artificial locks on the Garonne; hydroelectric production in the 1930s-1950s demanded greater volumes of water to generate reliable electricity, justifying high mountain reservoirs; and industrial agriculture after WWII created its own justifications for artificial reservoirs.

Irrigation-fed agriculture transformed the territory's previous farming culture, creating new incentives to convert the multi-crop, regional market farms, like those familiar to Yves Daros' grandfather, into export-producing commodity farms run by the current generation. Commodity crops are particularly water hungry, and, in a region that only receives twenty-two inches of rain a year, required heavy investment in irrigation. Largely underwritten by the French state, much of this investment coincided with a need to resettle thousands of French citizens fleeing Algeria after that country gained its independence from France in the early 1960s. Many of these "*pieds noirs*", as they came to be known, came from families who operated farms on colonized lands in Algeria. In the 1960s, as the region welcomed this influx of migrants, the issue of water was still framed principally around maximizing its contribution to state-led economic development. The newly established Adour-Garonne Water Agency did its best to accommodate new comers with existing users by going on an irrigation dam building spree. Dozens of small and moderate-sized dams sprung up during the period between 1960-1990 with co-financing by the state and irrigation district subscribers (Fernandez 2009).

Simultaneously, the French environmental movement began turning public attention toward the problems of pesticide and fertilizer pollution in the region's water system (Bess 2002). Presented as dangerous to both human and aquatic life, the discourse of *les écolos* helped shifted public opinion in the 1980s away from a logic of leveraging rivers for economic advantage toward concerns about the need to improve water quality (Veillard-Coffre 2001). Local environmentalists also put the brakes on new dam construction (Despointes 2009), which meant that by the late 1980s in on the Garonne, there was increasing demand on the water supply during the agriculturally intensive months of late summer, with little to no slack left in the regional irrigation system.

These developments came to a head when a series of severe drought years swept Southwest France in 1988, 1989 and 1991. The back-to-back crises in water availability struck a deep chord with the region's inhabitants, and particularly among the agricultural community, who lost thousands of bushels of wheat and corn for lack of irrigation water. The Water Agency sought both an immediate fix to the crisis and a longer-term solution to balance the interests of the different stakeholder groups in the region. In a moment of "institutional bricolage" (Douglas 1986; Weick 2000; Freeman 2007), the agency turned toward a water management tool developed by *Companie d'Aménagement des Coteaux de Gascgone* (CACG; the Gascony Land Use Company) a public-private entity that managed an adjacent water irrigation system called the Neste System.

Originally built under Napoleon, the Neste System was a regional development project intended to improve agricultural conditions in the Gascony region of France, a territory within the larger Garonne watershed. Despite somewhat promising soil and terrain for farming, Gascony's waterways only ran seasonally. By siphoning off water from the upper portions of the Garonne, however, the Neste's system of canals provided a regular injection of water into the seasonal stream beds of Gascony during months when the beds were normally dry. Local agriculture, as a result, had flourished in the region for over two-hundred years. In order to determine how much water to allow into the system at a given time (i.e. how much water to release from the upstream system of canals and reservoirs), the CACG eventually developed a metric called the "*debit* *d'objectif d'étiage*" (DOE), which translates roughly into "minimum flowrate target" (MFT). In other words, the MFT was used to measure the amount of water injected at the top of the irrigation infrastructure during dry moments of the year (the *étiage*).

As over-concentration of agricultural and industrial pollution became a growing problem in watersheds all over France, the CACG also introduced MFT measuring stations downstream to get a better sense of how much water remained in the system when the Neste's waterways rejoined the Garonne. This would give their managers a better sense of how well the overall territory was doing in diluting suspended pesticides and fertilizer pollutants. As a result, the CACG began managing their upstream injections based on these downstream flow-rate measurements, thus orienting management to take into better account extractions from the system that might also be detrimental to aquatic life. After the drought years of 1988-1991, the Water Agency seized on the MFT as both a crisis management tool to help determine when, in the case of drought conditions, the state should restrict irrigation rights, as well as long-term planning tool to help organize a crisis avoidance system, which it called the *"soutien d'etiage"*, or "low flow management".[53]

As currently constituted, "low-flow management" is a complex, socio-technical program for steering the regional water use. Following 1991, the Water Agency, under pressure to reduce the concentration of pollutants in the water as well as protect aquatic life, sought sources of stocked water that they could reserve and call upon should the situation repeat itself. The basic idea being

[53] In French, *soutien* means literally "support" and *étiage* designates the moment of the year in a river system when water levels are at their lowest, (i.e. the summer months). It connotes both the season and the phenomenon of "low flow". There is no equivalent word in English

when flowrates, measured at agreed upon points in the river, drop below pre-determined thresholds, upstream retaining dams release stored water with the aim of raising the volume of water for the entire river to avoid going putting stress on the *milieu*. In the event that the threshold is breached, the Agency alerts the state, and, under the authority of the local *préfet* (the representative of the state at the level of each *Département* in France), the state imposes restrictions on the access to water. A hierarchy of access has been designated, and agricultural use (i.e. irrigation) is first in line to face restrictions, while potable drinking water is last on the list.

When the Water Agency proposed "low-flow management" in 1991 to the Watershed Committee, the body representing all the major stakeholders of water in the region, as the solution to the drought, it was rapidly adopted. The *soutien d'étiage* was seen as a rational means for diffusing political struggles between opposing groups of water users by anchoring decisions about water distribution to decisions about how to set the MFT at different points of the river (Fernandez 2014).[54] But as one former member of the Committee told me, however, "Most people didn't really know the consequences of what they were agreeing to." (Interview with Alain Villocel, outgoing Director of CACG). For the "low-flow management" system to function there needs to be stored water available to "*soutien*" or "support" the moments of "low-flow" – particularly in the summer months. Currently, there is no slack in the system. In other words, the amount of irrigation allocations surpasses the amount of reserved water, especially at a few

[54] The MFT eventually spread and now has become the principal tool that other river basins in France use to allocate water in moments of scarcity. It is also now a central component to how the French government has tried to harmonize local water practices with regulations issued by the European Commission, in particular the Water Framework Directive, passed in 2000, which requires all EU member states to achieve good qualitative and quantitative status of waterways by specific dates. Others have been arguing that it should be pegged directly to another measure, called the "*debit minimum biologique*" (DMB).

crucial junctures in the system (see *Figure 3.4*). As a result, nearly every summer, somewhere in the watershed, farmers suffer from restrictions. These moments are not calmly accepted, they are indeed very contentious. They can even involve violence, with farmers burning things and dumping manure in front of the prefect's house.

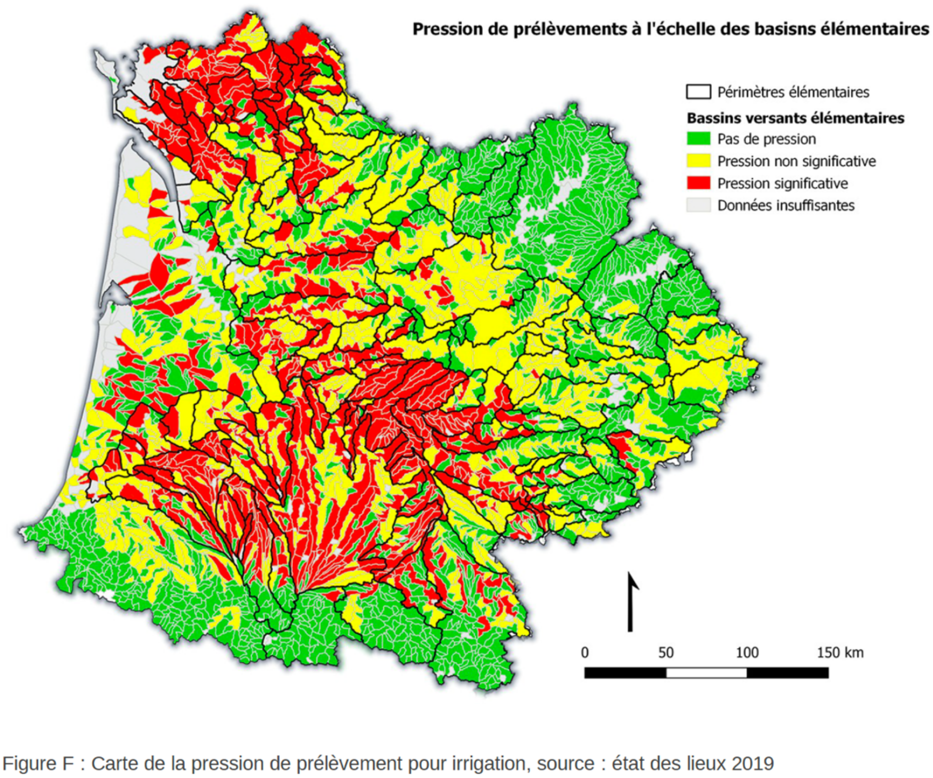

Figure 3.4. *Areas in the watershed where irrigation needs surpass reservoir supply. These areas are suffering from significant "structural deficits". (Source: DREAL 2020)*

Baptized by hectares of scorched fields and dry riverbeds in the late 1980s, the need to manage the "structural deficit" of the watershed became an article of faith among water engineers and planners at the regional water agency (Fernandez 2012). This collective experience of scarcity created a renewed push to maintain the status quo distribution system by compensating for the structural deficit with more reservoirs – in particular a massive new reservoir project in the small village of Charlas. The Charlas Dam, at 110 million m3, was written into the Water Agency's

1996 master plan (SDAGE) and was supposed to create relief for the entire system. The project's collapse has left lingering raw emotions in the region even two decades after its failure. Now, with the *Garonne 2050* study suggesting that future change will make things much worse, the issue of dams has returned again to the fore of local water politics.

Eco-social tensions around artificial reservoirs

Dams are a good example of what James Scott calls "high modernist" forms of governance (Scott 1998). They reshape landscapes in the image the economic ambitions of the administrative state, impose order on unruly natural processes (riverine flooding and droughts), and, once in place, are largely irreversible (or at least very difficult to remove). In the Garonne, these infrastructural fixes to an unreliable river system are deeply embedded in state led projects of rural development dating back to at least the *ancien regime* and the construction of the Canal du Midi (Mukerji 2009). The modern dam building era, however, is of more recent vintage, began in the 1930s when the state constructed a series of hydroelectric projects in the Pyrenees, succeeded by numerous large retention dams for the agricultural irrigation. Initially welcomed in the general and pervasive logic of progress that defined the period after WWII known as the *trente gloireuse* in France, dams also seeded some of the first conflicts over resource management that would lead to the birth of the modern French environmental movement (Lascoumes 1999; Ollitrault 2001; Bess 2003; Vrignon 2012).

Since the 1990s, environmentalists have successfully slowed dam construction in the Garonne region by sticking to three basic arguments: 1) dams disrupt what they call "ecological continuity", weaking the environmental health of river systems; 2) rather than alleviating the resource needs of existing users, dams end up creating surplus water that leads, in years of plenty, to an expansion of the number of water users, constantly pushing the margin of scarcity to the limit; and 3) dams are expensive and since their prime beneficiaries cannot afford to pay for them on their own, the public should have a much greater say in deciding whether to subsidize industrial agriculture or not (Le Bourhis 2004; Fernandez 2009; Despointes 2009; Germaine and Barraud 2013).

Ecological continuity developed as a concept along with the professional study of ecosystems as early as the 1960s in France (Illies and Botosaneanu 1963), although it took longer to emerge as a political concern (Perrin 2015). The introduction of the ecosystem into water governance created an important new set of demands on water availability (Lascoumes 2012). The environment went from being a synonym for the resource to being a user group in its own right, with a "claim" on the resource (Interview w/Denis Salles, sociologist and member of scientific committee of AGWA). Dams, as the science showed, are major disruptors of life in river systems because they break rivers into segments, ruining the ability for different aquatic life to move upstream and downstream (Stanford and Ward 1993). A new vocabulary of "*milieu*", biodiversity, and patrimonial species emerged in French water politics in the 1990s as a counterweight to decades of talking about and treating rivers as either a resource or a dumping ground for industrial and agricultural by-products (Sironneau 1992). Rather than adapt the ecosystem to the needs of users, this new discourse admonished users to fit their uses to the limits of the natural system.

Another dissatisfaction among environmental groups was that, despite a constant expansion of artificial reservoirs during the 1960s-1990s, demand never seemed to diminish. Dam building was a heavily engineered response to the Garonne's natural fluctuations that were also harmful to aquatic life. In other words, the "structural deficit" that justified the construction of irrigation reservoirs seemed to grow in tandem with the very efforts designed to close the deficit (Gaudin and Fernandez 2018). Rather than satisfy outstanding needs, new reservoirs often succeeded in adding new users to the system, or giving existing users the means to expand and intensify their production. This tendency to optimize use is constantly putting pressure on the overall ecosystem, and should not, according to the environmentalists, be a legitimate argument for constructing dams.

The final argument against the construction of new dams comes down to a matter of cost. In the battle over the Charlas Dam, this proved the decisive argument that environmental groups used to bring the project to a halt. By pointing out that farmers, the prime beneficiaries of Charlas, were unable to pay for the dam themselves (through increased water concession fees, for instance), environmental groups were able to put immense pressure on the elected departmental councils, who the state expected to provide roughly 40% of the dams financing. By influencing the political outcome of elections in the Department of Haute-Garonne in particular, the environmental opponents of the dam sunk political support for dam financing, which by 2003, succeeded in sinking the whole project (Interview with Remy Martin, former Director of the *Federation pour la Protection de la Nature et l'Environement*).

The Watershed Committee (and the Water Agency), had approved the construction of Charlas, but they were compelled to put the project indefinitely on hold. In lieu of canceling the project, they passed a resolution in 2006 proposing two intermediary steps: the first was to conduct a study of alternative sites (essentially a decision to avoid admitting defeat, since there had already been multiple studies of other potential dam sites, with none of the alternatives satisfying the kind of criteria that the Charlas site fulfilled). The second was to launch a prospective study analyzing the effects of climate change on the availability of water in the river basin up to the year 2050, the report *Garonne 2050,* whose diffusion and conclusions I was following around the water basin (Interviews with Francoise Goulard*,* lead author of Garonne 2050 and senior engineer at AGWA; and Claude Miqueu, President of the Adour-Garonne Planning Commission).

With their newfound influence on water politics, environmental groups began arguing more forcefully post-Charlas that farmers in the region should adjust their farming techniques. "Before we can talk about new resources", as one environmental leader in the region told me, "farmers should prove that they are making better use of the water they currently have" (Interview w/Remy Martin, former Director of the *Federation pour la Protection de la Nature et l'Environement*). More than any other crop, corn had become villainized by environmental groups as ill-adapted to the region's environment. Nearly sixty percent of irrigation in the region is dedicated to corn.[55] The image of water waste that many environmentalists evoked in conversations with me was of the pivot irrigation system spraying water indiscriminately into the

[55] Recent figures indicate that corn for animal feed accounts for 57% of irrigation withdrawal in the Garonne watershed. Other cereals and oleaginous crops (sorghum, soy and sunflower) account for 15%, alfalfa and other fodder 8%, seed corn 7%, commodity vegetables 7%, and fruit trees 6% (DREAL 2020: 12).

summer heat over a field of corn, the drops of water evaporating before they even hit the soil (see *Figure 3.5*). Anticipating future scarcity, for environmental groups, means radically reshaping farming practices to accommodate decreasing water availability during the summertime. Potentially banning certain crops altogether.

Figure3.5. *A field of young corn under conventional irrigation near Moissac, June 2014. While taken prior to the peak of summer heat, the photo captures the idea of water waste.*

Practices of economizing water

With the failure of Charlas, farmers in the region were left with very little room to maneuver. If they wanted to rebuild favor with politicians and the public, they could not continue operating in a way that was cast so easily as wasteful by opponents of irrigation. As a result, in the wake of Charlas, local agricultural chambers and farming syndicates in the region have significantly expanded their investment in a variety of material practices intended to reduce water use. These include better mastery of soil hydrometry, installation of precision irrigation systems, improved design of small-scale water retention structures, new tilling techniques, and crop-shifting (including experiments with genetically modified crops designed to be planted earlier in the season).[56] This ensemble of approaches toward reducing water use are not unique to the Garonne region, but they became locally salient in a particular political context linked to the loss of public support for large scale dam infrastructure.

The need to develop what is also called "demand-side management" introduced changes in material practices that, once the results of the *Garonne 2050* were released, created new political openings for farming groups to address the problem of water scarcity under conditions of climate change. All these practices change how water is used, but they do not dramatically change what it is used for – industrial, competitive, export-driven, commodity-oriented agriculture. During my field work, I visited farmers implementing some of these different techniques to see how they fit in with the Water Committee's calls for developing a "culture of anticipation". We see that the suite of practices targeting efficiency have material effects on the water basin, but also fold into existing logics of cultivation by helping to rehabilitate arguments for supply-side management, i.e. dam building.

Optimizing the moment of irrigation

[56] Of the different innovations mentioned here, I do not cover new tilling techniques designed to "grow" the soil, i.e. encourage the complex microbial, fungal, and rhizomatic relationships that characterize undisturbed soils to take root again. A great deal of experimentation has gone into improving the soil so that it retains more water. Relevant examples were being implemented in the region at small scale by farmers opposed to industrial models of agriculture (for instance, I visited farmers practicing BRF tilling, or *bois ramiale fragmenté*). Since this chapter is focused particularly on the commodity-oriented, export farming community, I leave this example out of the evidence.

It is a muggy day in late June, 2014, and I am standing at the edge of a corn field with Celine Cazenauve. She is an irrigation consultant with Agralis, a weather monitoring and agricultural services provider founded in 2003 in the southwest of France. The field belongs to one of her clients, a farmer with 120 acres of corn tucked along a bend of the Garonne River near the village of Jusix. The land is among the best agricultural land in the region, where the river valley is flat and wide, and the Garonne itself has room to spread around, creating giant meanders that overflow during high flood seasons, distributing rich minerals from the mountains around the plain. The corn next to us is waist-high, its slender, full-green leaves quivering in a slight breeze.

Cazenauve and her colleague François are here to install an environmental probe in one of the farmer's parcels. Their client comes out to meet us in overalls and a checkered, short-sleeve collared shirt, the first two buttons open. He's in his early 70s. It is very hot for mid-June, as if summer arrived in single, stifling week. Big storms have been menacing the region for the past few days, with massive thunderheads forming mid-afternoon only to rumble and dissipate without shedding a drop by early evening. Luckily, it's been a generally wet year, and the water tables are stable, so the farmer isn't too concerned about the coming weeks. But some of his neighbors have already started irrigating. Cazenauve says it is too early and unnecessary. "They must not be clients of ours", she says. "We wouldn't tell our people to waste their water yet!"

After a bit of debate about where to install the soil probe, we crawl back into the Agralis car and head down a dirt track between two fields of canola and corn. After driving about three hundred meters we stop and François begins pulling the soil probe and pounding tools out of the back of the car. The probe itself, called the EnviroSCAN Plus, is manufactured by the Australian company Sentek and consists of four pieces: a long skinny array of sensors that will go in the ground, a plastic tube casing that will go around them, and then a two-part metal pole structure that will rise directly above the probe. Attached to the bottom part of the pole is a small box housing a battery, a modem and a computer that records readings from the probe. At the top part of the pole, which stands a couple feet above our heads, is a solar panel that powers the measurements and an antenna that broadcasts the data to Agralis' computer servers back near Agen, about an hour drive away (see *Figure 3.6*).

Figure 3.6. *François plugging holes after installing a Sentek humidity probe in a corn field.*

As we walk into the field, Cazenauve narrates their activity, "We look for a parcel that will really serve as the zone of reference, the baseline, for the farm. We have to identify the zone that will be the most representative of the rest of the farm." She presses a handheld device into the ground with a long, pointed tip and a small gauge on top that resembles the pressure gauge of a bike pump. It measures the porosity of the soil. "We need to find a place that's not too compacted, because it will give us poor readings compared to the rest of the field." Arriving at a spot she likes, she gives François a thumbs up and he begins tapping down a long hollow tube that extracts a core of soil, creating an empty space in the ground for the probe that which will measure the amount of moisture in the soil.[57] In terms of the lifecycle of the corn in this field, the probe's sensors will allow Agralis to see at what depths the plant is drawing water, which will allow them to track the development of the root system and hold back on irrigating a field too soon, which not only wastes water but also prevents good root development.

After the installation, we return to Cazenauve's office near the airport of Agen, to see what the readouts from the probe look like on Agralis' computer interface. On the wall behind Cazenauve's desk is a poster titled "Windbreaks: benefits of hedges as protection against the wind", with diagrams showing different configurations of hedge structures composed of different species of plants and the height of the windbreak they provide. Next to the poster is a detailed map of the region of Lot-et-Garonne, Agralis' main service territory. The map is spread over a metal backing, and there are little colored magnets covering the map, indicating each rain gauge, climate station, and soil sensor managed by Agralis. This distributed network of devices is an example of an anticipatory infrastructure, which, as Cazenauve says, "Allows us to provide a wider irrigation notice to the local chamber of agriculture for when everyone in the sector should

[57] To install the probe, they first insert a plastic PVC pipe into the emptied hole, that will serve as a casing for the probe, which itself is a long, fragile tube with open sensors resembling computer micro-processors. The processors are separated every ten centimeters by double bands of metal. The metal generates a small magnetic field that, when humidity is higher or lower in the soil, deform the frequency of the field in a manner that can be precisely recorded by the sensor boards at intervals of ten, twenty, thirty, forty, and fifty centimeters deep. More water in the soil reduces the frequency of the field, and less water creates a higher frequency.

think about irrigating their crops."[58] But they also give Agralis the means to provide higher resolution information to their clients in whose fields the probes are installed.

At her desktop computer, Cazenauve pulls up data outputs from a probe installed in a kiwi farmer's orchard. The graph shows time on the *x axis*, and depth of soil on the *y axis*, with a line charted for each sensor readout, indicating the amount of humidity in the soil at each depth level measured by the sensor. The black lines spike when water has arrived either from a rain event or an irrigation event, and slowly dwindles until the next arrival of water (see *Figure 3.7*). Even when mature, the kiwi, according to Cazenauve, only throws roots down around 40cm deep. Agralis created a specific threshold range for this farmer's field, delineating a zone above which you do not want to irrigate, and a zone below which the plant will suffer if you do not. Essentially, if you irrigate too early you saturate the field, squeezing oxygen out of the soil, but as humidity levels drop into the 10-30cm zone, the farmer needs to irrigate, or the kiwis will become hydrologically stressed. Looking at a week of probe data, Cazenauve can see that the farmer irrigates every day, sending out about 11-15 milliliters of water per round of irrigation, using micro-jets. "This producer, I know that he follows this interface every day and it has completely changed his use of water. Now, he never over saturates."

[58] Some of these stations are actual human observers – retired farmers, widows, a furniture maker, an accountant who is an amateur storm chaser – volunteers who conduct daily readings of thermometers and rain gauges which they report back Agralis (and a farming weather advising association that predates Agralis). One farmer in Duras, Cazenauve tells me, has been recording for fifty years. Other stations have been modernized to provide automatic readings of rain levels, temperature and barometric pressure, among other climatic variables. "The network is still a mix of observers and automated stations." Through these observations, Agralis has access to a database of over half a century of data "that gives us a deep point of reference for the whole the region. Through this data," Cazenauve reports, "we've been able to observe the warming of the region. No question about that. For the rain, however, we always have the same amount over the last 50 years. It hasn't changed. What's changed is when the rains come."

Figure 3.7. *Celine Cazenauve at her desk at Agralis, reviewing the readouts of a Sentek probe in a client's kiwi orchard; each peak of the black lines shows a round of irrigation or rain event.*

With a couple clicks of her mouse, Cazenauve pulls up data from the year before on the same parcel of kiwi, when the producer was not yet following the curves himself, but instead relying on the weekly bulletins from Agralis and his own intuitive cultivation practices developed over the years. The data showed that he often still over-irrigated, sending his orchard into the saturation zone by pumping too much water into the earth. "Being able to visualize the humidity makes a big difference in terms of changing the habits of the producers. It's not enough that I just tell them. Once he started seeing the lines, he changed the way he farmed. The probe *serves like a pair of glasses to help the farmer see what is happening under the ground*, and it lets him ‘steer his irrigation’ activity in a way that would otherwise be hard to imagine” (*emphasis my own*).[59]

This move away from “blind”, habitual modes of irrigating toward an irrigation calibrated to the preservation of the resource is a good example of what the Watershed Committee and Water Agency mean when calling for a “culture of anticipation”. Being able to visualize how much water remains in the soil as it interacts with root systems and ambient air temperatures is now a widespread form of “anticipating”, on short intervals of time, the urgency and the efficacy of water use. In the matter of the past fifteen years, these technologies have been largely integrated into most farmer’s practices through the local irrigation bulletins.[60] But other forms of anticipation, involving slightly longer temporal horizons, and slightly more complicated issues of ecosystem integration, have also emerged as a practical response to political opposition to large-scale irrigation infrastructure.

Reducing the ecological footprint of retention ponds

A few months prior to meeting Cazenauve, I visited the headquarters of Unicoque, an agricultural cooperative that is the largest producer of nuts in France. Located in Cancon, in the same department as Agralis, the cooperative focuses primarily on walnuts and hazelnuts, what the French call shelled-fruits, or *fruits à coque*. Waiting for me when I arrive at the entrance to

[59] In the French, Cazenauve, and most other professionals in this field, use the term ‘piloter l’irrigation’, which can be translated into ‘steering’ or ‘guiding’ the irrigation in English, but retains a much stronger sense of navigation in the French – like piloting a boat, or an airplane. It is an incredibly appropriate verb in the context of ‘cultures of anticipation’, because it implies moving in a fluid space (air or water) that requires constantly getting one’s bearings and adjusting to changes in the speed or direction of winds and waves in order to maintain the proper trajectory of travel.
[60] Other Crops in the region that rely on these “irrigation bulletins” are corn, soy, sunflower, tomatoes, strawberries, melon, peppers, prune, apple, peach, almonds, hazelnut, pears.

Unicoque's offices are Jean-Luc Reigne, the company's Managing Director, and Frank Brosset, Development Director for Terres Sud, another agricultural cooperative. Numerous people had recommended that I visit Unicoque to learn about its design of an ecologically sensitive retention pond, which, combined with precision agriculture was showing promising results in terms of reducing the amount of water their producers withdrew during the *étiage*.

We start out in a small conference room, with a large white board, which Jean-Luc uses throughout our conversation to illustrate some of the problems of water management they face in the region. "The Garonne," Jean-Luc begins, "does not suffer from a general structural deficit. The problem is a *chronic summer deficit*", he says, emphasizing each word at the end of his sentence. "If we just looked at the current flow of the river, at Agen, today, in April, there is enough water flowing over the course of a single day to provide for all the irrigation needs of the region during a dry summer." The variability between the winter flow and summer flow, however, is inverse to the demand. Farmers do not need the large volumes of water that pass in the winter and spring—they need the water that trickles by in the summer.

The region around Cancon, situated in rolling foothills between the Lot and Garonne rivers, is a territory that is particularly vulnerable to this variability. For Jean-Luc and Franck (and many other farmers I spoke with), the logical remedy to the mismatch between supply and demand is to take advantage of the moments of abundance to store water for use in the periods of deficit. But aware that constructing dams, even very small ones, had become politically problematic, Jean-Luc says that Unicoque "Decided that we needed to look at what really prevents these kinds of projects from being built? Where was the opposition? And in speaking with the Water

Agency, the DDT (*Direction départementale des territoires*), and fishing and conservation organizations …we reached some design specs that define what we call *lac collinaire 2.0*, or second-generation retention ponds."

The design criteria for these second-generation ponds are intended to respond to previous criticisms of the *lac collinaire* by attempting to reduce their impact on the environment.[61] The principal difference of these new retention structures, compared to those built by Yves Daros and his father in 1976, for instance, is that they do not, in theory, disrupt the ecological continuity of the river system – they are "open-circuit" reservoirs. While a dam is thrown up across a stream to create the reservoir, a canal is also built that bypasses the retention pond, so that, outside the winter months when the farmer might fill her reservoir, the stream (and all the aquatic life connected to it) flows through this artificial channel (see *Figure 3.8* below).

[61] The five core design elements for the *lac collinaire 2.0* include: 1) zero-waste of stocked water (stored water must be used efficiently and transparently); 2) reservoir storage dimensions that include a buffer volume of water to ensure zero withdrawals from the river system during a severe *étiage;* 3) a reservoir plan based on pluriannual management (i.e. storing more water in wet years than is needed, in anticipation that water may be less abundant the following year); 4) a commitment by reservoir owners to participate in the *soutien d'étiage,* by making it possible to put water back into the system if needed; 5) and the installation of filtration systems to ensure that any water returned to the system is of the same quality, if not better, than the water that was initially removed.

Figure 3.8: *Jean-Luc Reigne, demonstrating the design of the Lac Collinaire 2.0. The triangle sketch (representing a reservoir) on the left is the current model, with the red marker line representing the artificial channel that maintains ecological continuity.*

Other alterations include the installation of water meters to measure exactly how much water is taken out of the system; filtration fields (typically a small wetland) planted at the head and terminus of the retention pond, so that the water from the stream is filtered both arriving and departing; and the size of the ponds themselves are built with up to 30% excess capacity compared to what the farmer expects as her annual needs. "If I know I need 25,000 m^3 to water my hazelnut orchard and my corn in a given year, I build a retaining pond that is not 25,000, but 30 to 35,000m^3. This way, I know that in normal times I will always have 10,000 m^3 in reserve that I can carry over to the next year. This 30% is what gives me the margin to have a true pluriannual management of water." Because of this, the new ponds are much larger than the earlier ponds built during the first wave of retention ponds 1970s and 1980s. Ponds like those built by the Daros (before permits were needed) were on the order of 12 – 15,000 m^3; these new ponds are more on the order of 35,000-50,000 m^3, with a dam height of 5.5m (see *Figure 3.9* below).

Figure 3.9. *Second-generation, 50,000 m^3 retention pond in the Commune of Montflaquin, with recently planted hazelnut orchard in the background, each tree roughly the size of a soccer ball.*

Unicoque's initiative has led to a gradual increase in the permitting and construction of new retaining ponds in the region (see *figure* above). According to Jean-Luc, the fact of working with a reserve of water, rather than pumping water directly from local streams alters farmers' relationship with water management. "If I irrigate without a supply of stored water, I reason in the moment. If my cereal crop needs water, I have an interest in withdrawing as much as I can from the river so that my crops can last as long as possible. But the minute I have a reservoir, my logic shifts. I know that each time I draw down the supply, I will have less in the future, so I ‘steer’ (*pilote)* my use with greater precaution, economizing water I have today, knowing I may have less tomorrow.”

This rationale of storage resembles, in its most basic form, the logic of owning a bank account, and thus it translates the challenges of farming into a framework that nearly everyone, farmer and non-farmer, can understand. It is a retelling of the old story of how capitalism defeats the tragedy of the commons by enclosing the river (via individual retention ponds) and forcing farmers to reconcile their irrigation needs with the constraints of their reservoirs. Not only do retention ponds allow farmers to better anticipate their use of water during the *étiage*, according to this story, but also *between* seasons of *étiages*. In this way, the narrative of the second-generation retention pond also absorbs or *anticipates* environmentalists’ critiques about improving efficiency while maintaining ecological continuity, responding to both through a material design that in turn serves as an argument for building more small-scale dams across the entire watershed.

This secondary layer of anticipation operates as a kind of semiotics in that the material practices developed by the farming community also participate in justifying which types of activities should be counted as adaptive or not. Franck Brosset, who attended some of the workshops and forums around *Garonne 2050*, says that the expectations from climate change make the case for second generation retention ponds even clearer. “According to what we know from the scientists,” says Franck, “we will not have a diminution of annual quantities of water within this region. We will rather have an accentuation of the effect ‘wet period / dry period’. The wet periods will be wetter, and the dry periods will be drier, and also longer."[62] In this way, the findings from *Garonne 2050* reinforce the argument that in the future, the agricultural sector will have to balance, or anticipate, even more aggressively between wet and dry periods. "With climate change," as Jean-Luc pursues, "not only does our design remain credible in terms of limiting the impact of these kinds of structures on the current ecosystem, it also emerges as an appropriate response to a future where this variability is going to worsen."

Transitioning to less water-demanding crops

Finally, in terms of anticipating scarcity, there are also cases of farmers moving away from irrigation entirely as a means of mitigating losses from potential water restrictions in the future, or what is called crop-shifting. Romain Stigliani operates a large farm with his father in the Gers region of the Garonne watershed. In 2003, a severe heatwave hit France and manifested itself as a drought across the entire Garonne. It deeply affected the Stiglianis and their neighbors. Romain was only in high school, but was already working the fields. "We were able irrigate our corn in the early stages of its growth, but the day that the Préfet announced a restriction, we had to stop watering our crops. When you no longer have the right [to irrigate], you no longer have the right." For long stretches during the *étiage* it stayed between 35 and 40 Celsius, and their corn fields suffered enormously, the ears shriveling on their stalks. "That's when you really realize how much your livelihood is at the mercy of the weather."

[62] Franck adds that the simulations of Méteo France also show an augmentation of "evapotranspiration potential" (ETP), which means as it heats up, water will vaporize more quickly, leaving less water for plants to convert into biomass. "So, the crops, and especially the summer crops, are going to need more water [in the future] to maintain an equivalent level of irrigation [compared to today]. We do not know yet exactly, but this increased heat may require 20% more in terms of water needed, regardless of whether there is a deficit or not in a given year."

Stigliani does not remember exactly by how much they lost, but when the family calculated the marginal return on their corn, it was largely inferior to what they would have gained if they had grown something like wheat – i.e. a crop that does not need irrigation. “That’s when my parents and grandparents decided to stop planting corn.” Giving up corn, however, is not easy. As a feed crop, corn produces more calories and protein per hectare than its nearest alternatives (soy, sunflower, wheat, etc). Although corn needs more water than these other plants, it is in many ways more efficient in converting sun and H_2O into carbohydrates and protein (especially if dosed with fertilizer and other synthetic products). One hectare of intensively grown corn yields about 100 bushels, or roughly 10 tons of dried cereal. Sunflower, the next closer contender, produces only about 3-4 tons of dry seed per hectare, while dry wheat produces between 2-2.5 tons per hectare. And the market for corn, as feed for livestock and the principal ingredient in processed corn syrup, retains higher market value than most other cereal crops. But corn also has more inputs than other crops, and with each added input comes more intermediaries, dependencies, uncertainties, and costs.

In addition to the cost of water and the cost of diesel for the pumps, irrigating also has a labor cost. “We have two self-propelled reel sprinklers, or *enrouleurs*, but they need to be constantly moved to cover the crops, and moved again during the harvest so they don’t trip the harvesting machines. During these periods, we work from 7am till 2am, so it is very exhausting.” Then there is the cost of fertilizer, the cost of the harvester, which is more expensive than a types of harvesters, and the cost of drying the corn, which, if the summer is humid, will require more mechanical drying, fueled either by gas or oil.[63] “If all goes well,” Stigliani summarizes, “corn is

[63] Stigliani adds that a neighbor told him recently, who is still in corn production, that drying the corn, “if you do it yourself, or if you hire a contractor, will cost around 10€ a ton in less humid conditions, and up to 25-30 € when it’s

what generates the most economically; but if all does not go well, it's also the crop that creates the most debt, because of all the expenses."

Concerned that the canicule of 2003 was perhaps not an isolated event, the Stiglianis "anticipated" the negative impact of future drought events by withdrawing from corn production altogether and reducing their exposure to the variability of the Garonne. Yet the water they annually forgo cannot be properly considered "returned" to the river. Despite no longer irrigating, the Stiglianis continue to pay their membership fees to their local irrigation ASA, which cost about 2,000-3,000 € a year. They hold onto the rights because without them, their farm is worth less should they ever want to sell. Besides, if they left the ASA, another farmer would quickly replace them (there is a wait list), and while they seem to be doing fine without irrigating for the moment, who knows what the future may bring. So, while they have adjusted to a new mode of cultivation, they continue to anticipate against a water deprived future in which their existing concessions may allow them to change agricultural strategies again, hedging against yet unknown trials and tribulations.

The dilemma of efficiency

The three vignettes capture how the means for anticipating the future and managing water scarcity have shifted in the Garonne since the failure of Charlas. Whereas previous approaches to

very humid." He is constantly doing calculations in his head as we talk, converting water, land, oil, and seed into bushels of grains and cents on the euro, moving fluidly between his memories growing up, and a kind of calculative rationale that Marx would very much recognize as a fine specimen of *homo economicus,* and Thomas Jefferson the yeoman farmer. "The price of corn right now is about 170 € the ton, approximately. But when you dry corn, you take out water, thus you reduce its weight. One ton of dried corn corresponds to about 1.2 tons of freshly harvested corn. So you need to keep all of this into account."

scarcity favored the construction of new irrigation reservoirs, prevailing ecological concerns have succeeded in reinserting the *milieu* back into the water politics, rendering this particular "infrastructural fix" socially problematic. The general public is less and less supportive of enacting the 1970s version of the river. In response, the idea of improving water efficiency, i.e. growing the same amount of crops with less water, has become a governing mantra heard across the river basin (Interviews with Denis Salles, sociologist and member of scientific committee of AGWA; and Sylvie Rocq, Director of the *Syndicat Mixte d'Études et Aménagement de la Garonne*).

Under these new constraints, local agricultural cooperatives, chambers of agriculture, agricultural service organizations, and individual farmers have adapted their farming practices in ways that have made material differences in terms of how water's presence is accounted for, in the here-and-now and in the future (and different moments of the future). This has led to subtle shifts in the composition of agricultural territory. Now, networks of soil monitoring probes, precision irrigation technology, ecologically-continuous retention ponds, and the effects of voluntary shifts away from irrigated agriculture, are a part of the material landscape itself. This is what the emerging "culture of anticipation" evoked by the Water Committee in its last Master Plan looks like on the ground.

In conjunction with encouraging improved efficiency measures, the Adour-Garonne Water Agency (AGWA) has further rationalized water use in the region by trimming irrigation concessions. In 2013, the AGWA finished a major review of existing water rights in the Garonne, aimed at harmonizing irrigation concessions with the objectives of the European Water

Framework Directive, which aims to secure a measurably "*bon état*" (good state) of the *milieu* within specific agreed upon frames of time. Known as the "water withdrawal reform" (*reforme des volumes prélèvable*), the goal (it is still very much ongoing) is to bring withdrawals into accord with all "minimum flowrate target" (MFT) thresholds in the basin to ease the "quantitative disequilibrium" that exists during the étiage.[64] This "disequilibrium" is on the order of 200-250 million m3 per year. The AGWA set a target of reducing the amount of total water available under existing concessions from 900 million m^3 to 818 million m^3 (DREAL 2020) and starting in 2017, the Agency began implementing the program by cancelling excess claims and introducing updated water-metering technologies to better account for withdrawals at the point of extraction.

Efficiency gains coupled with the retirement of water rights should alleviate an over-withdrawal of water during critical moments of scarcity (thus decreasing the likelihood of irrigation restrictions), and also alleviate demand for major new dams (thus decreasing political conflicts around contentious infrastructure projects), all while allowing much the same form of agriculture to persist. Theoretically, if restrictions are enforced, the Agency's hydrology model should have no problem making its calculation stick. But it is hard to determine how tightly these efforts are coupled and whether they really reduced pressure on the environment. As one former dam system operator told me for his region the Gers, "The State isn't capable of enforcing their restrictions. What do you expect with one agent from the water police in a department of 5,000 water-pumping farmers to do? He doesn't have the means to do his job. It's a constant cat and

[64] In a conversion of language, the "structural deficit" of the Water Agency's previous Master Plans has become "quantitative disequilibrium", perhaps, as some informants told me, to avoid the same resistance among some actors (particularly ecologists) when wter governance is framed around managing "structural deficits".

mouse, and we know that the mice win" (Interview w/Alain Villocel, outgoing Director of CACG). In talking with the different actors implementing efficiency techniques, the anecdotal evidence suggests similarly ambiguous results.

Celine Cazenauve's kiwi farmer, who used the hydrometry probes "like a pair of glasses" to better steer his irrigation was excited because by better controlling his water use, he was, as Cazenauve told me, "planning to expand his orchard production". The same is true for Unicoque's new generation retention dams and precision irrigation systems. The cooperative's goal is to expand their number of producers in the Lot-et-Garonne. As Jean-Luc Reigne, the cooperative's president reported recently "Our plan is to pass from 10,000 tons of annual production to 30,000 tons of production in 2030-2035" which means increasing the number of orchards, "at a rhythm of about 350 new hectares under cultivation each year." (Marchand, 2018). A sign of the success of Unicoque's vision is that in 2020 they became for the first time in their history a supplier to Ferrero, the massive Italian agri-food conglomerate, locking in a substantial new market for their producers (Pellicier 2021). The water of the Garonne, stored in more ecologically palatable retention ponds, is thus transformed, via Unicoque's hazelnuts into creamy pots of industrially produced Nutella, a spreadable snack sold in supermarkets around the world. In each of these cases, optimizing the resource largely means that savings are available to be put toward production of some other crop or to expand networks of existing production.

While linked to the problem of enforcement, this tendency also captures what economists call Jevon's Paradox. In the 1860s, in England, there was concern that rapid industrialization was exhausting the country's coal supply at a pace that would jeopardize its future economic growth.

Public authorities and factory owners alike put a heavy emphasis on making better use of available coal, i.e. using it more efficiently, to preserve supplies. But English economist William Stanley Jevons, in a small tract called *The Coal Question; An Inquiry Concerning the Progress of the Nation, and the Probable Exhaustion of Our Coal Mines,* demonstrated the folly of this thinking. “It is wholly a confusion of ideas to suppose,” as Jevons wrote, “that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth” (Jevons 1865). The more “productive” coal is rendered, according to Jevons, the greater attraction for other economic actors to take advantage of these gains in efficiency and convert them to greater production. Thus, the paradoxical effect of efficiency as a means of resource management leads to more resource use, not less.

Although now over a century-and-a-half old, the relevance of Jevon’s Paradox, also called the “rebound effect”, has started receiving attention in the scientific literature on water management just in the past fifteen years (cf Tirado et al 2006; Pfieffer and Lin 2010; Gómez and Gutierrez 2011; Dumont et al 2013). As one of these early papers concludes, “More efficient irrigation technology generally increases the ‘effectiveness’ of a unit of water, but the water ‘saved’ can be used to increase yields, shift to more water intensive crops, or expand irrigated acreage” (Pfieffer and Lin 2010: 23). Water conservation gains, in short, risk being partially or completely offset by these other effects. As the literature on Jevon’s Paradox and water use points out, voluntary shifts in irrigation and cultivation practices will be unlikely to result in major reductions in the agricultural use of water unless they are coupled with enforceable quota reductions (i.e. retiring permits) or increases in the water of price (Gomez et al 2011).

The water rights reforms in the Garonne, validated by the Watershed Committee in 2017, began a process for rationing water rights in "oversubscribed" sub-basins of the Garonne. These sub-basins, constituting about thirty six percent of the overall watershed's cultivated land (including the Tarn and the Lot-and-Garonne), are the persistent spots of tension in the watershed (see *Figure 3.4* above). The difference between irrigation needs and available surface water in these areas are largely responsible for the 200-250 million m3 of "quantitative disequilibrium" experienced across the entire basin. In these areas, the Water Agency has set a calendar for gradually reducing 82 million m3 in allocations between 2017 and 2027.[65] The reforms, however, were introduced and passed before the results from *Garonne 2050* were finalized and published (the actual reduction amounts were negotiated between the Water Agency, the *Direction Départementale des Territoires* as early 2010).[66] This is problematic because by introducing sacrifices on the farming community, the reforms legitimize a portfolio of future water rights, making further restrictions politically fraught, despite the fact that the 2017 reforms are not calibrated to the effects of climate change on future disequilibrium.

Revenge of the reservoirs?

By integrating efficiency into actual water management practices, farmers have conceded to the logic of other water stakeholders, particularly environmental groups, about how to address

[65] The package of policies included in the Water Rights Reform also include the construction of 69 million m3 in new water supply as a necessary solution to achieve something closer to equilibrium between the Minimum Flowrate Target metrics and existing withdrawals, although the construction of these new reservoirs has been heavily contested, and very few new reserves have been built. See (*Pointe d'Etape sur Reforme des VP*; 2020, p3)
[66] As staff from the préfecture reminded the Watershed Committee at the meeting where they validated the Water Reform Plan of Action: "This current plan of action…does not take into account strategies that may be necessary to implement in the context of consequences from climate change because the reform process did not consider the climate dimension" (Prefet de la Region Occitaine, 2017; p4)

problems of scarcity. Operating at different scales of space and different horizons of time, these various practices align with calls to nurture a “culture of anticipation” around water in the Garonne. Even if the broader impacts of these practices on the environment are somewhat ambiguous, the portfolio of efficiency-oriented interventions show that farmers have at least been trying something other than building dams to solve their water problems. As a result, the various initiatives to improve water efficiency have gained the agriculture community a measure of credibility with the state and other water users (DREAL 2020). In so doing, they have also expanded the debate about what activities will be counted as adaptative under conditions of climate change.

In the *Garonne 2050* study, the Water Agency analyzes future basin change with regard to the same two variables discussed in the reform of water rights: the level of the “minimum flowrate” targets” (MFT) and the “withdrawal rights” (WR; “*volume prélèvable*” in French, or VP). Projecting future water availability in 2050 against different assumptions about these variables, the report offers nine scenarios of what the disequilibrium of tomorrow will look like (see *Figure 3.10*). For the MFT (called the DOE in French), they look at what it would take, in terms of water management, to maintain flowrate thresholds at their current levels in 2050 (assuming a 40%-50% lowering of overall river capacity during the *étiage*), what it would take if thresholds were lowered by 75%, and what it would take if thresholds are pegged to the global trends suggested in climate projects (i.e. if the MFT was left drop by roughly 50% in 2050). In terms of WR, they look at a scenario of 20% additional reduction in irrigation (on top of what farmer’s achieved following the 2017 action plan), maintenance of existing irrigation concessions, and an increase of 20% in allowable irrigation (seen as a scenario that compensates for great evapotranspiration and water demand by plants in a warmer climate; i.e. a scenario necessary for maintaining existing cultivation).

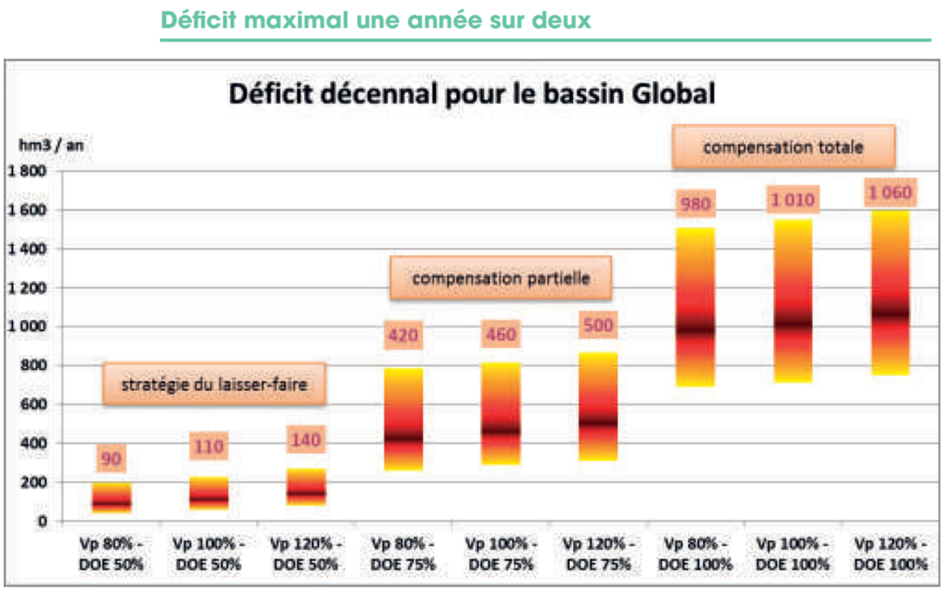

Figure 3.10. Garonne 2050 *analysis of future water deficits in the region under conditions of climate change. Scenarios use three differing assumptions for two principal variables: the MFT (called DOE in French), held at 50%, 75%, and 100% of current targets; and Water Allocations (called VP in French) (held at of 80%, 100%, and 120% of current levels).* (Source: Garonne 2050)

What the report articulates is that under nearly all the scenarios, major increases in savings from better irrigation practices (including crop-shifting away from corn), will be sorely insufficient to maintain the "low-flow management" (*soutien d'étiage*) system currently in place for protecting the *milieu*. The volume of water needed to maintain current MFT thresholds (DOE at 100%) is around 1 billion m^3, roughly an order of magnitude higher than what is available today in the basin for the *soutien*. Even if the MFT was reduced by 50% and water rights restricted by another 20% on top of th recent reforms, the region would still need a dam roughly the size of Charlas to return to "equilibrium". Integrating the results of *Garonne 2050* into their Master Plan, the Water Agency determined that "In parallel to our efforts aimed at improving water efficiency, in order to resolve the problem of disequilibrium in our subbasins we must also create new reservoirs in the collective interest. They will be indispensable in certain territories if we want to achieve [our environmental aims]" (Comité du Basin 2015, 162).[67]

This strange logic of the need for dams in order to protect the *milieu* from a changing climate makes perfect sense for someone like Yves Daros, the corn farmer from the Tarn (and Watershed Committee member) that we met at the beginning of this chapter. For him, the study *Garonne 2050* shows that even if "we limit agricultural withdrawals from the watershed, and succeed in reducing water use across all sectors of human activity…we will still need to store much more water just to protect the ecological life of the rivers over the course of the year." Dams, in other words, are justified not just as a means of economic protection for the export-oriented agricultural sector that Daros represents, but for the environment itself, as currently defined by the legislated metrics of the MFT that environmental groups helped establish. Initially something that ecologists in the Garonne sought to install as a means for better regulating and restricting the negative effects of irrigation on the health of the river, the MFT now has come back to bite these actors as its legal status becomes a prime reason for creating new dams.

Coping with adaptation compromises

This chapter set out to make sense of how expectations of climate change are already affecting the management of water in the Garonne River basin in the southwest of France. Picking up on the aspirational idea of a "culture of anticipation" evoked by the regional Water Agency in their

[67] As another state agency writes even more recently, with regards to reforming water rights in light of climate change: "In pursuing these reforms, we must focus on implementing the climate adaptation plan by controlling the amount of water withdrawals, adapting of practices, *and accelerating and elaborating…new reservoir projects.*" (DREAL 2020: 68)

first climate-influenced Master Plan, I turn the phrase into a lens to help analyze how different stakeholders are positioning their own actions and claims around water in the face of increasing scarcity. This emerging culture operates, at least discursively, like a productively ambiguous rallying cry, providing interpretive flexibility for environmentalists, intensive farmers, hydroelectricity engineers, and city water utility managers, allowing then to agree on the collective problem of increasing resource scarcity, if not on its solutions. At the same time, enabling anticipation also has material manifestations, such as the further instrumenting of natural systems to better understand (and model) the interaction of humans and the *milieu*, and the *milieu* and the climate.

Cultures of anticipation thus create new indicators and ways of orchestrating these indicators in order to creates positive anticipations of resource management and territorial decision-making. These same processes, however, also create defensive modes of anticipation, i.e. willingness of groups to adopt other's points of view about the future as a means primarily of protecting certain territorial projects (i.e. irrigation dams, in our case, and the way of life they support) from being writ out of the picture. In other words, actors embrace notions of collective anticipation, while simultaneously advancing partial, situated, and less-collective interests. Focusing on one set of partial interests, I followed the conventional farming community in their development of a range of anticipatory actions in their material farming practices. I chose these individuals and families largely because, in the process of adapting to increasingly unreliable water supplies, they have the most to lose among all the human actors I met in the watershed.

“The culture of farming,” as one of the Watershed Committee members told me, “is a rural culture. It’s not about numbers – even though farmers are more and more dependent on numbers – but about practical things. Above all else, it’s about practicality, ‘If we do this, does it, or does it not work?’” (Interview w/ Alain Villocel, outgoing Director of the CACG). At the same time, as this case shows, farmers are also savvy at interpreting and using the numbers produced by others to their advantage. By putting a great deal of doubt on the idea that savings to water from changes to irrigation practices alone will meet the challenge of climate change, the *Garonne 2050* study has reinforced the notion that dams merit another review. Farmers can argue that achieving the “*bon état*” for the *milieu,* even under moderate scenarios presented by *Garonne 2050,* will require storing more water for the “*soutien d’étiage*”.

After three decades of extremely contentious battles, spurred largely by concerns about the ecological effects of dams, climate change seems to be changing the terms of the debate around new reservoirs. “Whatever scenario we assume,” as Yves Daros tells me, “they all point to the need to create more reserves in water for the future.” The irony of this is that it was the environmental groups that supported putting climate change on the regional water management agenda. They were active participants in *Garonne 2050,* while agricultural representatives ignored many of the first participatory workshops and scenario building sessions, only becoming involved when the report shifted tactics to do explicit modeling of the two variables affecting them most directly, the minimum-flowrate targets and water withdrawal rights (Marquet and Salles 2014). In having adopted efficiency measures, farmers give the impression of having sacrificed and compromised, even as these measures yield ambivalent results for the environment, since optimization frequently leads to intensification of production. This perceived sense of “doing their part”, in turn, paves the way to justify the construction of dams as a necessary form of adapting the region to climate change. Collectively, it’s as though the commodity farmers say, “We agree that climate change is a problem; we’ve even cut back on our water use. What else do you want? You’re not trying to put out of business, right?”.

The issue of climate change raises precisely the question of what deserves protecting. Which ways of life will be valued and which will not? The events tracked here show how assessments of climate impacts on natural resources turn the ontological status of nature itself into a political object (Scoville 2019; Fourcade 2011; Espeland 1998; Cronon 1991). Because expected changes will create conditions that overwhelm the functioning of the *milieu* as it is currently constituted, the human-designed systems established to maintain these relations are subject to revaluation, adjustment, and potential abandonment as a new climate-altered “nature” installs itself. Following the different reactions of regional actors to the conclusions of the study *Garonne 2050* shows that the same vision of change can be shared among disparate actors, but the solutions posed by that change can reinforce or reopen long-standing social antagonisms. As this case suggests, adapting to future change in resource-bounded communities such as watersheds will put increasing stress on publicly managed stakeholder processes to select and justify which forms of anticipation gain priority over others. Finding ways to agree upon how to collectively share unequally distributed forms of vulnerabilities will be a key political task for the climate-constrained future.

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Claude Miqueu, Dec 17, 2013, President of the Commission du Planification for the Comité du Basin, Toulouse

Jean-Luc Reigne, April 9, 2014, Director of agriculture cooperative Unicoque, Cancon

Franck Brosset, April 9, 2014, Development Coordinator Terre Suds, Cancon

Romain Stigliani, May 29, 2014, farmer, Pellfigue

Celine Cazenauve, June 11, 2014, field technician at Agralis, Jusix and Agen

Yves Daros, July 6, 2014, farmer and agricultural representatives on Comité du Basin Peyrolle

Sylvie Rocq, Sept 12, 2014, Director of the *Syndicat Mixte d'Études et Aménagement de la Garonn*e, Toulouse

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Alain Villocel, Sept 17, 2014, former Director of Companie d'Aménagement des Coteaux de Gascogne and representative of dam operators on Comité du Basin, Lac de l'Arret Darre

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Chapter 4

The treadmill of protection: How public finance constrains climate adaptation[68]

> "Well, in our country," said Alice, still panting a little, "you'd generally get to somewhere else—if you run very fast for a long time, as we've been doing."
>
> "A slow sort of country!" said the Queen. "Now, here, you see, it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!"
>
> – Carroll (1865), Alice's Adventures in Wonderland

Outrunning the Anthropocene?

The environmental changes associated with the Anthropocene are expected to inflict significant impacts on societies around the globe (IPCC, 2018; Steffen et al., 2015a). In this paper, I argue that responding to the physical threat of these impacts, which are both abrupt and incremental,[69] will require massive increases in public spending on programs of protection and adaptation (Bapna et al., 2019; OMB, 2016; Reidmiller et al., 2018; WEF, 2020).[70] Accelerating change will put added pressure on authorities to protect existing sources of public revenue, which make protective expenditures possible in the first place (GAO, 2019; Shi and Varuzzo, 2020). In areas where state

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[68] A version of this chapter appeared in *The Anthropocene Review* (online first, published on June 20, 2021).

[69] Abrupt and catastrophic impacts include extreme weather, heat waves, drought, and wildfires; more incremental impacts include nuisance flooding, salt water intrusion, greater variation in precipitation, and increased airborne smoke. Both forms of change, abrupt and gradual, invoke different coping strategies and institutional capacities (Kates et al., 2012).

[70] While some of this spending will be private in nature (Goldstein et al., 2019), the bulk will involve major infrastructure spending, which historically depends on large outlays of public monies.

and municipal revenues depend heavily on the economization of environmentally exposed forms of natural capital (i.e. commodity extraction, agriculture, tourism, and real estate development), it will be hard to avoid using public money, at least in the short-term, to protect resource-dependent activities, even if those activities contribute to growing social vulnerability. I call this paradoxical situation—when the material conditions that support public financing of protective measures are linked to the root drivers requiring those measures to begin with—the "treadmill of protection."

Protection treadmills exist where policymakers mitigate the negative effects of the Anthropocene without fundamentally trying to shift society's status quo relationship to natural ecosystems. They are treadmills insofar as environmental threats and vulnerabilities persist, with "protection" really serving as ephemeral damage control. One element affecting governments' running of the treadmill, as just mentioned, is overreliance on revenue from natural resource-linked sectors. If one or more such sector is prominent in a given territory, it can be expected that those sectors will receive greater protection than other economic sectors. Another element affecting the operation of the treadmill is governments' fear of unsettling perceptions of risk as they relate to the financial worth of the built environment. That is, if public officials admit that the current built environment is untenable due to the changing profile of natural hazards, they risk both capital flight and devaluation of local property assets. So, officials pretend they can protect existing assets in order to avoid this potentially economy-wrecking admission. Finally, a third mechanism of the treadmill is linked to existing politics of disaster recovery, particularly prevalent in the U.S., that encourage local governments to socialize natural hazard losses as inevitable events deserving of national sympathy and federal taxpayer relief (Dauber, 2012).

Louisiana, where the Mississippi Delta meets the Gulf of Mexico, exhibits all the hallmarks of being caught in such a "treadmill." Since the 1930s, the state has lost a startling amount of its coastland—an area roughly the size of Delaware—due to eroding soils, subsiding swamps, and rising sea levels (Wiegman et al., 2018). The situation puts Louisiana in a bind because much of its wealth is derived from activities connected to the coast, such as commercial fishing, petrochemical manufacturing and, in particular, offshore oil and gas extraction (Barnes et al., 2015). The state's lucrative tourism industry, built on the region's unique mix of Native, Creole, and Cajun cultural heritages, is inextricably linked to the bayou ecosystem, as are a significant portion of the state's residents, whose personal wealth is bound up in the value of properties and homes located on rapidly disappearing coastlands. As a result, the Louisiana government has launched an ambitious $50 billion coastal protection plan aimed at preventing future land loss, which it views as an existential threat (CPRA, 2017).[71]

The single largest source of funding for the state's protection measures are mineral royalties from the oil and gas sector. This only seems appropriate, given that the sector is one of the principal contributors to Louisiana's environmental precarity; yet, it is also one of the prime beneficiaries of protection. The industry has successfully cast itself as both victim of land loss and as an irreplaceable source of revenue for dealing with that loss. "Every lease sale in the Gulf of Mexico that doesn't happen," an industry lobbyist recently warned, in response to a federal moratorium on new offshore extraction permits, "prevents tens of millions of dollars from going to Louisiana's

[71] As the public-facing Comprehensive Master Plan for a Sustainable Coast puts it: "In view of rising seas and the migration of people away from Louisiana's southernmost parishes, some have asked, 'Why not just give up on Louisiana's coast?' The answer is simple: Our combination of resources, cultural heritage, and geography are found nowhere else on earth. The delta of one of the world's great rivers, vast resources, and wetland habitats—these things are all here in coastal Louisiana and worth celebrating and protecting" (CPRA, 2017: 11).

coastal work" (Mosbrucker, 2021). The conundrum this poses for coastal planners is evident in the state's most recent Comprehensive Master Plan for a Sustainable Coast, where officials dedicate significant resources to secure the industry's immediate viability, despite its deleterious effect on longer-term trends of loss (CPRA, 2017: 97−99; Day et al., 2019b). Faced with few good options, state planners resemble the Red Queen in Alice's Adventures in Wonderland, running faster and faster just to stay in place, expending increasing public resources to defend patchwork pieces of an unraveling coastline.

Drawing inspiration from early work in U.S. environmental sociology, this paper develops a conceptual frame for understanding this dynamic. I speculate about the economic logics and political conjunctures that lead to particular projects of protection in particular places. How do these projects build and maintain citizen support, even as their limitations become increasingly apparent? I begin by tracing the genealogy of the treadmill idea from Allan Schnaiberg's pathbreaking work on the political economy of environmental regulation. Turning to the Mississippi Delta as a case study, I use the concept of the treadmill to help explain trajectories and trade-offs of coastal protection in Louisiana in which public monies are marshalled to protect private interests that paradoxically create the problems which public monies are solicited to resolve.[72] Although the paper focuses particularly on Louisiana, in the final section I consider other situations in the U.S., and elsewhere, suggesting the applicability of the treadmill for thinking critically about the broader political economy of adaptation in the Anthropocene.

[72] Primary data for the case study was gathered during three weeks of field work in Louisiana in November of 2019, where I visited different coastal communities and conducted 10 semi-structured interviews with state officials from the Coastal Protection and Restoration Authority (CPRA), the Governor's office, the Office of Community Development, the Department of Insurance, coastal engineers, landscape architects, oystermen, and members of the Pointe-au-Chien Indian Tribe. Other documents reviewed include scientific articles on Louisiana's wetland loss, state budget and economic analyses, rating agency reports, and a wide range of planning documents, criticism, newspaper accounts, and prior restoration plans predating the CPRA's current Coastal Master Plan.

Repurposing the treadmill of production

My concept of the treadmill borrows from an analytic approach within U.S. sociology known as the "treadmill of production" (ToP1) that strives to explain why environmental policies adopted by societies organized under capitalist exchange frequently fail to reduce the environmental degradation produced by that exchange (Schnaiberg, 1980; Schnaiberg et al., 2002). First theorized by Allan Schnaiberg, ToP1 considers that the rise of consumer capitalism in the U.S. in the 1950s led to a major deterioration of the country's ecosystems. This deterioration, according to Schnaiberg, takes the form of a "treadmill," where consumption-fueled growth calls for increasing "withdrawals" from the environment (in the form of minerals, fossil fuels, water and other natural resources), which result in an expanding set of environmental "additions" (in the form of pollutants, synthetic molecules and other industrial byproducts) (Buttel, 2004; Schnaiberg, 1980). Public authorities, while theoretically in a position to rein in this dynamic, fail to do so in any meaningful way because the public operations and services they provide are secured by taxing the wages, property, and purchases linked to consumption. The liberal democratic state, in other words, is dependent on maintaining the treadmill.

Schnaiberg situates the rise of ToP1 within the period following World War II, the same moment when human impacts on the biosphere enter what earth system scientists call the Great Acceleration (Steffen et al., 2015b). Construed in treadmill terms, the Great Acceleration documents, at a planetary scale, the most pronounced versions of Schnaiberg's "withdrawals" (extraction of ground and surface water, marine fish capture, and tropical forest loss) and “additions” (excess production of methane, nitrogen, and atmospheric carbon dioxide). Unlike earth system science, however, and of relevance to those interested in the political ramifications of the Anthropocene (Bai et al., 2016; Dalby, 2016; Görg et al., 2020; Malm and Hornborg, 2014), Schnaiberg linked his notion of the treadmill to a materialist theory of the relation between environmental policies of the state and the political economies of capitalism. Since state expenditures on social programs depend on tax revenues generated by the activities of the private sector, public officials interested in expanding social services, in Schnaiberg’s analysis, often find themselves advocating for endless economic growth (Schnaiberg, 1980, cf Chapter 5). “Social and ecological problems,” in this framework, “are frequently resolved by speeding up the treadmill (i.e. generat[ing] more taxes to spend on ecological problems)” (Schnaiberg et al., 2002: 4), which in turn, generates new ecological problems.

Over time, the balance of power between capital and public authority has become less and less favorable to the state. Subsequent ToP1 analyses argued that beginning in the 1980s, in the U.S., firms gained increasing autonomy from labor constraints (through offshoring and automation) while they also played a greater role in policymaking (through corporate lobbying and direct donations to political campaigns) (Gould et al., 2008). As a result, state services in the U.S. have even been replaced to some extent by corporations, who “keep governments tied to reproducing the treadmill by their “generosity” toward previously state fulfilled mandates (e.g. money to schools; local governments; arts and culture, sports, health expenditures etc.)” (Schnaiberg et al., 2002: 18). For Schnaiberg and colleagues, this process of unwinding the welfare state’s social commitments has only gotten worse as conditions of neoliberalism have expanded globally (Pellow, 2007; cf also Kentikelenis and Babb, 2019).

Developed 40 years ago, ToP1 provides a useful framework for explaining the persistent failures of the "Environmental State." In adapting the concept to make sense of Anthropocene concerns, however, it is also necessary to update some its notions. The first is how ToP1 conceives of the "environment." The simple model of "withdrawals" and "additions" fails to capture the changed nature and scale of vulnerabilities afoot in the Anthropocene. With its positive feedback loops, non-linear disequilibrium, and climatic shifts, the Anthropocene is not simply about managing a growing accumulation of externalities, but about coping with the emergence of a world fundamentally more erratic and less hospitable than the one in which human societies have lived for the past millennia (Dalby, 2019; Keys et al., 2019). The problem for government, thus, is not only about restoring a degraded planet, but about mediating an increasingly unpredictable and destructive environment.[73]

A second modification is in response to Schnaiberg and his colleagues' conception of capitalist "production" as a relatively homogenous force that operates alike across all geographic space. The problem of "protection" (i.e. the need to spend money on protective solutions from environmental change), is not operative everywhere to the same degree. It will be felt the hardest in places facing higher levels of Anthropocene-enhanced vulnerability (coastal areas, arid-zones, permafrost settlements, etc.). Thus, protection efforts will struggle or succeed not only due to the material resources and institutional capacities of a given government, but also due to its location (Biermann

[73] The notion of degradation, for instance, depends on a prior baseline against which degradation can be measured. While this use of baselines works well for describing changes to ecosystems, it is less adapted when describing changes to the atmosphere. "Additions" of greenhouse gases may push the atmosphere into a new "state," but it is a stretch to call this new situation a "degradation," since there are previous examples in the geologic record of earth achieving similar levels of atmospheric greenhouse gases.

et al., 2016). This geographic unevenness of vulnerability will determine, in part, how capitalism "resettles" in an Anthropocene-altered landscape, which will carry, in turn, cascading consequences for governments' abilities to both project their territories as havens for ongoing investment and maintain the social and economic wellbeing of their own citizens.

Finally, ToP1 does not address the tightening links in developed economies between natural disaster risk, finance capital, and local property markets (Taylor and Weinkle 2020). This nexus presents a lurking public problem whose dimensions are difficult to clearly discern because of uncertainties about the scale and potential speed at which people's accumulated wealth (in the shape of fixed assets such as homes and small businesses) may become "stranded," i.e. converted into negative forms of wealth no longer worth the value of the mortgage or insurance needed to secure them (Keenan and Bradt, 2020). Such a situation could trigger defaults on par or in excess of the 2007 subprime crisis (Federal Reserve Bank of San Francisco, 2019). One place where all these processes are on display is the increasingly fragile Mississippi Delta, to which I now turn before returning to my analysis of the "treadmill of protection."

Anthropogenic factors of vulnerability in the Mississippi Delta

Louisiana is home to the broad alluvial fan of the Mississippi River, the seventh largest deltaic system in the world. These systems are among the most vulnerable to environmental change on the planet (Renaud et al., 2013; Elliott et al., 2019). Like many major deltas, the Mississippi's is heavily impacted from over two centuries of intense human-made modifications. As a result of these alterations, Louisiana's coast is facing one of the fastest rates of land loss in the world. In the past 100 years, nearly 2000 square miles of coastal wetlands have vanished into the Gulf of Mexico (Day et al., 2019a).

Of the many anthropogenic factors driving this loss, the most consequential is connected to land subsidence (Frederick et al., 2019). Subsidence has numerous causes, but the prime source is what hydrologists call "sediment starvation". Across the Mississippi watershed, upstream dams, irrigation diversions, and flood levees, stretching from Great Falls, MT to Boothville, LA, prevent the pulse of seasonal sediments from reaching the deltaic plain. This infrastructural hardening of the river essentially "starves" coastal areas of the land-nourishing soil required to replenish delta lands. Lacking this fresh sediment, the coastal zone is sinking on average at the rate of 4 mm/year due to natural compaction of soils (Blum and Roberts, 2009; Kolker et al., 2011).

More local factors are also hastening the demise of the coast. Beginning in the 1920s and 1930s, major discoveries of oil and gas deposits under the bayou led to the development of an offshore extraction industry that laid thousands of miles of pipes, platforms, and pumping stations within coastal wetlands (Austin, 2003; Theriot, 2014). While boosting the state's fortunes, withdrawals from underground oil and gas reservoirs have drastically sped up coastal subsidence rates (in some areas by up to 24 mm/year) (Kolker et al., 2011; Yuill et al., 2009). At the same time, industrydredged pipeline channels and shipping canals accelerated saltwater intrusion into fragile brackish ecosystems, poisoning the root systems of the very plants that hold the land together (Wiegman et al., 2018; White and Kaplan, 2017). Finally, locally-extracted fossil fuels have added one last layer of coastal impact in the form of global sea level rise. Heat-trapping greenhouse gases released from the combustion of hydrocarbons (Louisianans, among others) are responsible for melting ice sheets and thermally expanding seas, which are advancing by roughly 2 mm/year into the wetlands of the Mississippi Delta (Day et al., 2019b; Jankowski et al., 2017). Combined with coastal subsidence, sea level rise is creating a "sinking" coastal margin of 5–6 mm on average per year. All told, Louisiana is facing a crisis of land loss of almost unparalleled proportions that coincides with (and is in part caused by) the rise of oil and gas extraction.[74]

Political economy of wetland restoration

Although concern about wetland destruction in the state was articulated off-and-on over the years, coastal land loss itself did not become a sustained political problem in Louisiana until the 1980s (Houck, 2015). Initially, local environmental advocates pointed to dredged canals and underground pumping as the principal culprits of wetland loss (Randolph, 2018). To combat these negative perceptions, oil and gas groups supported research on a wider set of factors, especially the role of sediment "starvation" due to upstream infrastructure (Priest and Theriot, 2009). By doing so, they succeeded in characterizing the sinking of the Mississippi Delta as the result of an infinitesimal number of geographically distributed actions for which nearly the whole nation was responsible. "You could entirely eliminate oil and gas dredging," as a leading industry lobbyist put it at the time, "and the wetlands erosion problem won't go away." (Getschow and Petzinger,

[74] While this situation is particularly stark for the fact that it is happening in the context of a developed economy such as the U.S., it echoes problems facing other oversubscribed deltas such as the Mekong, the Niger, and the Ganges rivers. Considering just the impacts of anthropogenic climate change in these areas (to the exclusion of other forms of anthropogenic forcing), economists estimate that "the costs of local rising sea levels for [global] coastal cities will be much larger than those due to socioeconomic changes, and could amount to US$ 1 trillion/year in the absence of appropriate adaptation measures" (Hallegatte et al., 2013).

1984; quoted in Houck, 2015: 270). Over the years, the industry successfully recast themselves as victims of land loss, just like the rest of the coastal public.[75]

Indeed, the nature of coastal vulnerability does put the oil and gas sector (and the state revenues it generates) at risk. Extraction in Louisiana accounts for roughly one fifth of all U.S. petroleum production (Barnes et al., 2015). The majority of that activity is concentrated along the coast, which links offshore oil and gas rigs to onshore storage tanks, refining facilities, and chemical manufacturing plants.[76] Given these embedded interests, efforts to combat land loss have not focused on regulating oil and gas activities, but on "restoring" the coast (Houck, 2015; Randolph, 2018). Early policy actions included enlisting help through federal appropriations (the "Breaux Act" of 1990) and earmarking state oil and gas royalties for exclusive use in restoration projects (the Wetlands Conservation and Restoration Fund Act of 1989).

These initial funding sources, however, proved woefully incommensurate with the scale of loss (Couvillion et al., 2013; Theriot, 2014). This became bluntly apparent in 2005 when Hurricane Katrina ripped through Louisiana's saltmarshes, stripping away thousands of acres of already weakened cordgrass that buffers coastal communities from storm surge (Dean, 2005). In response to Katrina, the state consolidated numerous wetland rehabilitation efforts into a state level agency, the Coastal Protection and Restoration Authority (CPRA), tasked with coordinating the fight against accelerating land loss. Additionally, the state's Congressional representatives succeeded

[75] As ToP1 might predict, when the state's broader campaign to "save America's wetlands" kicked off in the early 2000s, it was financed by none other than the oil and gas industry (Randolph, 2018). If there was one culprit that the industry picked out, it was the Army Corps of Engineers (i.e. the federal government), for building and managing all the upstream diversions and levees (Houck, 2015: 270–272).

[76] Louisiana's petrochemical industry, which relies on its tight proximity to cheap hydrocarbon feedstocks, turns offshore petroleum and gas into ingredients for shampoos, disinfectants, pharmaceuticals, cosmetics, milk cartons, adhesives, toys, wetsuits, furniture, electronics, and single use plastics, among many other consumer products.

in convincing their colleagues in Washington to redirect more federal fossil fuel royalties back to the Gulf states (rather than to federal coffers) through the Gulf of Mexico Energy Security Act (GOMESA), a maneuver that has opened up tens of millions of dollars annually for coastal protection and restoration.[77]

Preventing land loss requires immense resources. The CPRA's (2017) latest Coastal Master Plan, scheduled for an update in 2023, calls for US$ 50 billion to fund the projects in its 50-year pipeline. After accounting for inflation, this sum is likely closer to US$ 92 billion (Davis et al., 2015). In addition to GOMESA, the Breaux Act, and state oil and gas revenues, the principal funding mechanism for the Master Plan come from payments connected to BP, the British oil company. In 2010, an offshore oil rig drilling for BP, called the Deepwater Horizon, exploded, sending millions of tons of crude oil gushing into the Gulf. The disaster added to the ongoing coastal wetland crisis,[78] but also generated billions of dollars in settlement money for environmental restoration work. Table 1 charts the principal sources of current coastal protection and restoration funding.

Fund	Type	Duration	Amount
CWPPRA (1990 Breaux Act)	Federal Legislation	Annual (depending on Congressional appr.)	$30-$80m per year (w/15% matching state funds)
GOMESA + Section 8(g)	Federal Mineral Royalties	Annual (depending on federal lease revenue)	$140m cap starting w/ Phase II (2018)
Deepwater Horizon Funds	Corp. Liability Payments	Dispersed over 15 years	$5.787b
CIAP (Coastal Impact Assistance Program))	Federal Mineral Royalties	2007-2010	$495.7m
HUD National Disaster Resilience Competition	Federal Community Block Development Grant	2011-2013	$93m

[77] The proportion reserved for the four Gulf states is 37.5% of annual offshore revenues, capped at $500 million/year. For Louisiana, the full portion they can receive is $140 million, which they did for the first time in the 2020 GOMESA allocations.
[78] Globules of crude oil from the BP disaster aggregated in coastal wetlands, further degrading salt grasses and soils. The persistence of oil and its effects in these ecosystems is poorly understood. A recent landmark survey, published in the journal Nature, found that astonishing amounts of hydrocarbons were still present in over ninety species of fish a decade after the explosion; in other words, across the entire trophic chain of the region (Pulster et al., 2020).

State Surplus	State Funds	Depends on surplus and competing state needs	~$1b (to date)
Coastal Protection and Restoration Trust Fund	State Mineral Royalties	Annual	~$30m
LA Dept. of Transportation	State General Budget Funds	Annual	$4m
TOTAL	--	--	**$20.617b**

Table 4.1. *Principal sources of coastal protection and restoration authority funding 2007−2020. Sources are compiled from the fiscal 2021 report of the CPRA (2020) and Davis and Boyer (2015, 2017). Small sources of one-time, or infrequent funding, are not included; amounts in US$. m: millions; b: billion.*

The overall conclusion to draw from the chart is that, of US$ 20.617 billion in identified funding (Davis and Boyer, 2017), under $2 billion, or 10% of expenditures, come from local state resources. In addition, the bulk of the money (both state and federal sources) is tied to the success of the oil and gas sector. In other words, coastal protection and restoration, as currently proposed, is unimaginable without the ongoing exploitation of fossil fuel resources.

The CPRA has divvied up these federal and liability-backed investments into three broad categories of protection: structural protections (levees and flood gates), natural infrastructure (restored marshes, barrier islands, and sediment diversions) and what the Authority calls non-structural components (elevating homes, floodproofing larger buildings, and offering voluntary buyouts to some homeowners). Mindful of the need to appear to balance protections benefiting fishing communities as much as major corporations, all three components are vetted by the CPRA's Planning Tool, "a computer-based decision support software system" designed in collaboration with the RAND Corporation, that "uses optimization to identify. . .the projects that build the most land and reduce the most flood risk while meeting funding and other planning constraints" (CPRA, 2016: 18). Projects that secure current sources of state revenue, areas of high employment, and denser concentrations of property, for the least expenditures, get higher evaluations than those that do not.[79]

Guided by this optimization tool, the current Master Plan allocates US$ 19 billion for traditional structural investments, US$ 25 billion for nature restoration work, and US$ 6 billion for non-structural expenditures. Discussion of the agency's ambitious planning and policy approaches has received extensive coverage in both academic and popular writings (Day and Erdman, 2017; Gotham, 2016; Kolbert, 2019; Nost, 2019; Rich, 2020). Rather than reprising this literature, I will now shift to develop how the pressures facing Louisiana's coastal planners resemble what I call a "treadmill of protection," and argue why the treadmill is conceptually useful for thinking through emerging political and economic dimensions of "protection" in the Anthropocene.

Protection and its three elements of circularity

In this section, I identify three principal elements at work in producing and maintaining treadmills of protection. These elements are not present everywhere, but wherever they are, they will reinforce treadmill tendencies. Confronted by threatening consequences from Anthropocene-driven change, public authorities will face pressure to: (1) Protect, in the short-term, sectoral activities that generate large amounts of revenue for the state, even if these activities also exacerbate the vulnerabilities against which the state is protecting; (2) Protect against growing perceptions of risk that might undermine local property values, even though such efforts may

[79] My understanding of CPRA project prioritization was especially informed by my interviews with the Chief Resilience Officer for the State of Louisiana, conducted by Zoom on 10/24/2019, and with a CPRA assistant administrator and software engineer, conducted in Baton Rouge, 11/25/2019.

enhance future risk by encouraging people to "remain in place", despite increasing exposure; and (3) Offload local protection costs to central governments by relying on national disaster declarations, a process assisted by industries that benefit economically from such declarations. I take each dimension in turn, using empirical examples from Louisiana's coastal protection initiatives to elucidate the workings of the treadmill.

Protect existing sources of tax revenue

Like Schnaiberg's "treadmill of production" (ToP1), the "treadmill of protection" (ToP2), is driven by state dependencies on securing operating revenue from private sector activities. The oil and gas sector, along with refining, petrochemical and plastics manufacturing, account for roughly 25% of Louisiana's tax revenue and almost a quarter of state GDP (Duffin, 2020; Scott, 2018). Tax receipts from economic activity tied to these industries underwrite public education, healthcare, transportation infrastructure and funds for public security. Per ToP1, this makes public officials, whether Republican or Democrat, structurally unlikely to pass laws or regulations that seriously impede oil and gas operations. ToP1 helps explain how Democratic Governor John Bel Edwards, in a recent visit to the coastal town of Thibodaux, can argue in one breath that, "We have to be proactive. That's what coastal protection is all about," while declaring in the next, "We are a natural gas state. There's going to continue to be demand for hydrocarbons for a long time to come. . .20, 30, 40 years" (Karlin, 2019).

Where the Anthropocene divergences from Schnaiberg's concept of the treadmill, however, is the repositioning of the environment not only as an entity which capital degrades (ToP1), but now as an entity which undermines, in a systemic and unpredictable fashion, capitalist production (ToP2).

This new relationship of the environment to capital is particularly evident in the form of physical climate risks (e.g. extreme weather, heat waves, drought, and sea level rise) (Houser et al., 2014). Facing a "vengeful Gaia" (Lovelock, 2006), the state is forced to make increasing expenditures to secure existing areas of capitalist activities, while potentially exacerbating vulnerabilities, or "unprotecting," less capital-generative territories.

Recent restoration efforts in Louisiana resemble this operating logic. For instance, the optimization techniques used in the Master Plan create a strong rationale for spending on restoration projects that "maximize" state revenue sources by reducing what they call "estimated annual damages" (EAD) to those same sources. By turning avoidance of lost revenue into a benefit, the exercise makes it difficult not to prioritize protecting areas that also generate funding for coastal adaptation, which, as noted above, are primarily attached to the oil and gas sector. These kind of accounting tools, as scholars of critical finance have shown, often work to depoliticize processes of decision-making, cloaking administrative choice with an aura of rational calculation (Bebbington and Larrinaga, 2014; Hasberg, 2020; Samiolo, 2012).

According to their own tracking platform, the CPRA has finalized nearly 113 projects already, at a cumulative expense of US$ 6.558 billion (CPRA, 2020: 35−36). Restoration projects make up a significant part of these expenditures, particularly in the form of barrier island replenishment and marsh creation. Among the CPRA's first restoration expenses, beginning in 2012, have been US$ 250 million on the Caminada Headlands, a swath of marsh and barrier islands that shields Port Fourchon, one of the state's (and nation's) major oil processing and storage facilities (see *Figure 4.1*).

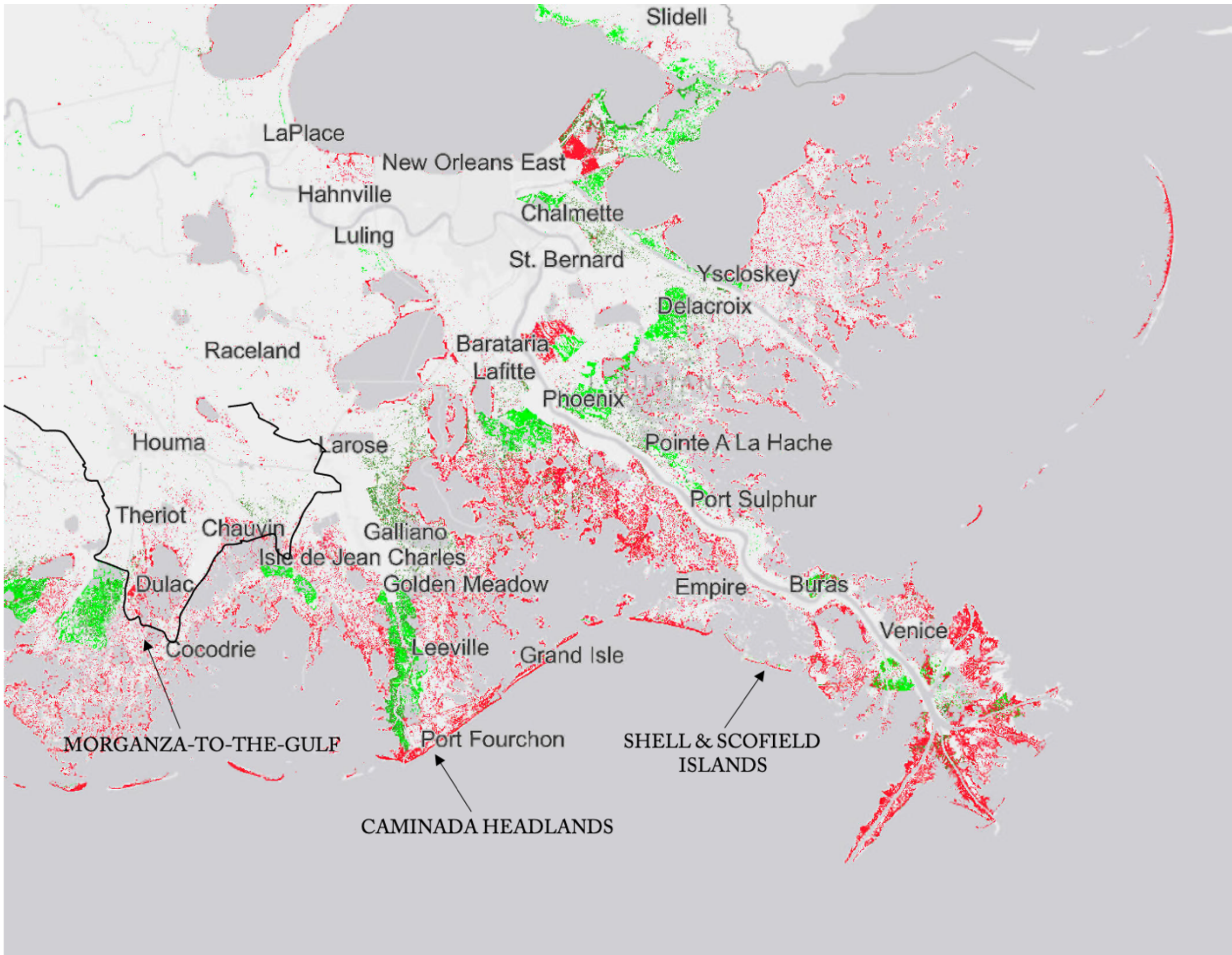

Figure 4.1. *Coastal Master Plan 2017 "Land Use Change" Data Layer.*
Shows 30 years of land use change (to 2047) in southern Louisiana under the CPRA's "medium environmental scenario" with an optimistic full implementation of the 2017 Master Plan; red = land loss; dark green = land maintained; light green = new land. (CMP data layers and visualizations are publicly available at https://cims.coastal.louisiana.gov/masterplan).

Disconnected from any significant communities, the Caminada Headlands accounts for roughly a third of current restoration expenditures (CPRA, 2020). In true treadmill fashion, these restoration efforts were made in response to Hurricane Isaac (2012), which destroyed millions of dollars of a previous restoration work following Hurricanes Katrina and Rita in 2005 (Louisiana Division of

Administration, 2015: 9−13). The CMP does not mention the costs of these previous efforts, nor does it budget for their reoccurrence.[80]

The bulk of protective spending (66%), however, has gone to structural projects. None more so than the massive Morganza-to-the-Gulf levee system (see Map 1). While some communities have been excluded from the system because of expenses (essentially ending their viability; cf Isle de Jean Charles), no major extractive infrastructure has yet to find itself on the wrong side of the levee or restoration plans.[81] For many frontline and marginalized communities already caught in the "slow violence" of Louisiana's former plantation system and toxic industries, none of this will sound like anything new (Allen, 2003; Davies, 2018; Yusoff, 2018). Yet the Anthropocene will likely deepen and expand current geographies of vulnerability by further constraining who and what gets protected (Anguelovski et al., 2016).[82]

Protect against risk downgrading

Another motor of "protection's" troubling circularity can be found in the increasingly complex ties between local property assets and global capital markets, a relationship that largely postdates

[80] In a further twist of the ToP2 screw, the majority of restoration expenses go toward purchasing diesel fuel to pump dredged sands to barrier island or marsh sites—sites undermined by the very fuel used to restore them (Wiegman et al., 2018).
[81] Identifying precisely who is benefiting from CPRA investments deserves its own empirical study. At the regional level, protection expenditures provide diffuse benefits, so it is not always easy to separate private gain from public good. That said, the oil and gas industry is, by any measure, a "frontline beneficiary" of restoration investments. Roughly 80% of land along the coast in Louisiana is private property, with the majority of that being owned by companies and holding groups affiliated with the oil and gas sector. Any effort to build back land positively affects these landowners (Theriot, 2014).
[82] For instance, the projected budget for the CPRA from 2020 onward tops $1 billion in annual expenditures, which is equivalent to roughly 4% of the entire state budget. As an increasing amount of public revenues go toward unevenly distributed "protective" expenditures, it is easy to imagine that some communities will face not just increasing exposure to the physical impacts of climate change, but potentially constrained spending on other social services as the overall pie of public money gets stretched thinner and thinner (Shi and Varuzzo, 2020).

Schnaiberg's conceptualization of ToP1. As the 2007–2008 credit crisis showed, future-oriented promises of payments wrapped up in property-based debt and insurance contracts are now an integral part of the system of investment and lending upon which consumer capitalism depends (Fligstein and Habinek, 2014; Krippner, 2012). In this system, local prospects of economic growth are increasingly entangled—through bond markets and securitized debt—with distant centers of finance (Aalbers, 2016). As a result, judgments by financial actors regarding a community's ability to protect the integrity of the built environment (i.e. what is the likelihood that a municipality will resist a particular hazard event), hold increasing sway over how risk and protection are discussed and framed by local authorities (Peck and Whiteside, 2016; Taylor, 2020).

Louisiana is at the forefront of this dynamic. In 2005, rating agency Moody's downgraded New Orleans' bond rating to junk status "in large part due to the unprecedented disruption to the city's economy and revenue that Hurricane Katrina caused" (Moody's, 2017: 10). This increased the municipal government's cost of borrowing capital precisely at the moment when it was most in need of cheap recovery money, a "nightmare scenario" for the city (Norton, 2019). While New Orleans eventually got back on feet, the city faced another downgrading event in 2019 by Fitch's, this time due to stress on the city's sewage system caused by climate-influenced floods in 2017 (Climate Nexus, 2017; Fitch Ratings, 2019). Such seesawing rates make it more expensive to maintain existing city services, let alone improve or expand them (Painter, 2018).

Institutional investors are increasingly expecting local governments to demonstrate that they are aware of, and trying to manage, these emerging risks (Flavelle, 2018). According to research by the asset management giant BlackRock, "within a decade," in the absence of decisive climate action, “more than 15 percent of the S&P National Municipal Bonds index [will] be issued by metropolitan areas suffering likely average annualized economic losses of 0.5 percent to 1 percent of GDP” (BlackRock, 2019: 10). In light of these kind of reports, efforts such as Louisiana’s Coastal Master Plan (whose largest protection expenses target New Orleans) can be understood as complex market signaling devices. They demonstrate (through advanced modeling capacity, active fundraising, and a steady pipeline of projects) the State’s appetite to shield a broad array of fixed assets from coastal vulnerabilities. The very existence of the CPRA and its ongoing expenditures serve to soothe nervous lenders, underwriters and other business interests, performing the value of the state’s protective intent (Nost, 2015; Wakefield, 2019a).

In the absence of such extravagant displays, the response of lenders and underwriters follows two likely paths: increase the cost of capital or withdraw services altogether. In both instances, the resilience of communities is undermined long before the event of a “natural disaster” as homeowners and businesses struggle to maintain access to insurance and credit, property values begin to suffer, and tax receipts upon which local governments depend for their operations and services begin to shrink (Elliott, 2018b; Gray, 2021; Shi, 2020). These perceptions of future risk, regardless of the performative efforts of the state, are slowly seeping into US real estate markets. Coastal property values, for instance, are already starting to experience forms of market discounting (Freddie Mac, 2016; Keenan and Bradt, 2020), hinting at the possibilities for future economic shifts that will see household wealth erode in tandem with disappearing wetlands in places like Louisiana (Federal Reserve Bank of San Francisco, 2019; Hino and Burke, 2020). By putting policy commitments and public money on the table, the Master Plan serves in some measure to forestall even greater negative risk assessments, while also potentially delaying more substantive efforts to move people out of harm's way.

Socialize local protection costs as widely as possible

Finally, a third major problem posed by the dynamics of ToP2, compared to ToP1, is that expenditures on protection against climate risks often generate "avoided losses," rather than new revenues. They do not, in other words, typically pay for themselves. As a result, in the face of mounting damages, private capital will attempt to offload protection expenses onto local authorities,[83] who will further try and pass those costs on to central governments (Traywick, 2016). As urban sociologists have shown, these efforts enjoy significant economic support from local networks of real estate developers, property owners, and building contractors—what Molotch (1976) called "growth coalitions." In the aftermath of disasters, such coalitions have become adept at treating federal aid as part of local "recovery growth machines" (Pais and Elliott, 2008), entrenching parochial interests around ongoing federal relief.[84]

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[83] An example: Farmers' Insurance Co. suffered multiple repeat flood claims in a 5-year period on residential properties it underwrote in the Chicago area between 2010 and 2014. In an effort to recuperate some of its losses, the company sued the city for "failing to prepare for the effects of global warming," pointing to an adaptation plan which Chicago had developed that recognized the need for investments in greater storm water management capacity (Paquette, 2014). The company withdrew the suit before it went to trial, but the attempt points to a broader logic of climate risk liability that will certainly expand as Anthropocene impacts worsen.

[84] This dimension of the treadmill is observable even in relatively wealthy, liberal jurisdictions, such as New York City. After Superstorm Sandy struck NYC in 2012, Congress approved a massive disaster recovery bill to assist the city in rebuilding. Many areas that flooded were not included in the Federal Emergency Management Agency's (FEMA) flood maps that determine whether or not residents must own federal flood insurance. FEMA updated its maps with new data on storm surge risk, but the expanded flood zones received immense push back from residents, tens of thousands of whom would now be obliged to purchase flood insurance. Officials from the city spent extensively on an engineering report that disputed FEMA's findings (despite NYC having already conducted sophisticated sea level rise risk estimates that shared FEMA's updated risk perceptions). Ultimately, the city succeeded in excluding thousands of homes from FEMA's new flood maps thus saving their constituents higher insurance premiums, while keeping federal taxpayers on the hook for future disaster bills (Elliott, 2018b).

Louisiana, over the years, has been remarkably successful at socializing local catastrophe losses through national disaster recovery payments.[85] Since 2005 alone, state communities have received over $100 billion in disaster aid from various federal programs and agencies.[86] Yet, much of this support is distributed in deeply unequal and racially targeted ways such that "reconstruction" leaves some Louisianan communities poorer and more vulnerable than they were prior to a disaster (Fussell, 2015; Sovacool and Linnèr, 2016: ch. 4). A decade after Hurricane Katrina, for instance, the black population of New Orleans still has not returned to its pre-storm levels, in part because these individuals have a much harder time accessing federal aid (Horowitz, 2020). Recent studies have found this form of dispossession pertains across the U.S. as recovery aid disproportionately flows toward white people of means, while minorities and the marginal (ostensibly those most in need of help) backslide further into precarity and debt after a disaster (Howell and Elliott, 2018).

The same vulnerabilities that lead to economic disparity for some, however, can be framed as an economic advantage for others. The CPRA, for instance, has characterized its planning around coastal protection as a lucrative form of economic stimulus. Officials expect the expertise they are

[85] The state already benefits from being one of the highest recipients for federal money for basic operations and social programs. According to annual Pew reports comparing the fiscal solvency of US states, Louisiana is the third most federally dependent state per capita. For every $1 the state sends to the federal government in taxes, it receives $1.52 back (Rosewicz and Huh, 2019).

[86] Accounting for federal disaster spending is very difficult, as relief arrives through numerous agencies and appropriation processes. To get at the $100 billion estimate for LA relief since 2005 ($98.849 billion, to be precise), I relied on the Louisiana Division of Administration's accounting of U.S. Department of Housing and Urban Development grants received since 2005 (Louisiana Division of Administration, 2020), the Federal Emergency Management Administration (FEMA)'s summary of its disaster mitigation and preparedness grants to the state from 2005 to 2016 (FEMA, 2020), and a new web portal run by an interagency federal task force that tracks all recovery money allocated, state by state, beginning in 2017 (U.S. Recovery Support Function Leadership Group, 2020). Supplemental Congressional appropriates for Katrina relief were not included in these databases, so these were added to the total LA relief estimates from Congressional Research Services reports (Lindsay and Nagel, 2019). While this $100 billion figure may contain slight double counting for 2005, it also likely underestimates total federal disaster expenditures in LA because it does not systematically account for levee and construction work done by the US Army Corps of Engineers after 2005, which, in addition to FEMA, accounts for a disproportionate amount of the state's federal disaster assistance.

developing around coastal planning will give Louisiana a leg up in the growing global sector of "water risk management" (CPRA, 2017). The success of Dutch engineering companies such as Deltares and Arcadis, who the CPRA paid to help develop their Master Plan, provide a business model for the state's own ambitions in the transnational sector of commercial coastal resiliency (Leitner et al 2018; Goh, 2020). With official disaster spending up by a factor of 10 in recent years in the U.S. compared to the past four decades (and declarations of major disasters doubling over the same period), this growing coalition of recovery experts can be expected to continue echoing state calls for increased protection spending (Stein and Van Dam, 2019).

Finally, the government's own Army Corps of Engineers is complicit in perpetuating ToP2 dynamics in Louisiana as well. The recently completed Greater New Orleans Hurricane and Storm Damage Risk Reduction System, built by the Corps for $14 billion following Hurricane Katrina, provides a stunning example of the need to rethink current approaches to protection. Begun in 2007, with the intention of securing New Orleans from the proverbial 1-in-100-year storm, the levees are already subsiding at a pace far exceeding modeled expectations, which, coupled with new sea level rise projections will likely render the entire system out-of-date within 4 years (Frank, 2019; US Army Corps of Engineers, 2019).[87] The immensity of these kinds of expenditures, however, create path dependencies that make it economically and politically difficult for policymakers to ignore calls for "one more round" of upgrades from constituents who are project beneficiaries (Anguelovski et al., 2016; Eriksen et al., 2015).

[87] In a comment in the Federal Register just after having finished construction on the massive hurricane system (whose levees stand at 35 feet), the Army Corps stated that, "absent future levee lifts to offset consolidation, settlement, subsidence, and sea level rise, risk to life and property in the Greater New Orleans area will progressively increase." Treadmill of protection logic if ever it existed.

Headwinds on the treadmill?

Despite different treadmill traps, ToP2 also generates resistance. In Louisiana, for instance, a number of parishes have brought lawsuits seeking damages from oil companies for years of neglecting laws that require companies to maintain (or backfill) dredged canals (ILR, 2019; SLFPA vs Tennessee Gas Pipeline Co., 2017). Even though courts have rejected these suits, they demonstrate that some local officials are willing to adopt more adversarial relations with industry. But demands for a fuller accounting from the oil and gas sector for their role in coastal degradation are, on the whole, tepid.[88] This is even more true to the extent that certain constituents in Louisiana (including broad swaths of negatively exposed communities) appear to harbor a general mistrust of government regulations, even those ostensibly designed for their benefit (Hochschild, 2016). "The oil industry not only molded the politics and economics of Louisiana," writes legal scholar Oliver Houck, "it molded the mind" (Houck, 2015: 192).

At the same time, increasing scientific evidence may also make it harder to ignore the economic consequences of staying on the treadmill. In the U.S. context, according to numerous studies, Southern states will likely face the largest economic impacts from climate change (Hsiang et al., 2017; Rasmussen et al., 2016; Schinko et al., 2020). Over time, it is not difficult to imagine that politicians and citizens from other parts of the country will feel less and less inclined to foot the bill for communities that do not demonstrate tangible progress toward reducing their vulnerabilities (Branch and Plummer, 2020; Stein and Van Dam, 2019). Also, as other states begin

[88] For instance, under the recent economic downturn caused by COVID-19, Louisiana Governor Bel Edwards joined other regional governors asking for more GOMESA royalties; importantly, however, the governors are not asking for oil and gas companies to pay more royalty payments, just for the federal government to redistribute more of the payments to the Gulf states (Outer Continental Shelf Governor's Coalition, 2020).

coping with their own increasingly deranged climates, tougher negotiations can be expected around who pays for what following a disaster (Schroeder and Stauffer, 2018). In other words, to the extent that protection costs begin to rise in multiple places, there may be more push back against treadmill effects as disaster recovery resources become constrained.

Beyond resistance to ToP2, there are also imaginative alternatives. Within the bounds of marketoriented solutions, some climate-impacted states in the U.S. are adopting carbon pricing schemes, and using the proceeds of these schemes to fund restoration and protection work. Different than legal liability, these "polluter pay" models spread the costs of greenhouse gas emissions across the entire chain of fossil fuel-based production and consumption. New Jersey recently adopted a carbon pricing mechanism and is allocating some of the proceeds to rebuilding wetlands along the Chesapeake Bay (McCabe, 2020). Louisiana, with the third highest per capita emissions in the country, could generate significant revenue from extractive industries that have benefited from decades of favorable regulations. Estimates suggest that just targeting electric utilities in the state (and excluding other large emitters such as refineries and petrochemical manufacturers), could generate between $110 and $293 million/year, which could be funneled into restoration work, while gradually ratcheting down climate-altering emissions at the same time (Davis and Boyer, 2017).

Another prime alternative to ToP2 can be summed up by what planners call "managed retreat" (Koslov, 2016). Retreat, in the context of coastal risk, "refers to the relocation of people to higher ground and associated efforts to plan and manage that movement" (Koslov, 2016: 362). It means adjusting conceptions of what constitutes "protection" and developing new expectations of coastal living. It follows similar calls for "amphibious" policy approaches (Jensen, 2017), where public spending focuses on what prominent New Orleans architect and planner David Waggonner calls "living with water," rather than against it (Waggonner and Ball, 2010). Amphibious thinking recognizes vulnerability as a persistent quality of coastal zones, as opposed to something that can be designed away (Wakefield, 2019b).

The CPRA gestures toward this line of thinking in its Master Plan through what they call "nonstructural" investments. These are investments that go to elevating homes, "floodproofing" larger structures, and buying out properties that cannot be protected. There is increasing evidence that offering people the means to proactively get out of harm's way can have significant upsides for both public finances and individuals' abilities to get on with their lives (Koslov, 2019; Mach et al., 2019; Siders et al., 2019). Yet, retreat is not a silver bullet; it introduces other issues of loss that are difficult to calculate and likely impossible to compensate (loss of community; loss of affective attachment to place) (Elliott, 2018a). In the most recent Master Plan, however, only about 10% of the overall budget is set aside for non-structural interventions, indicating that there is still little political will for this kind of strategy in Louisiana.[89]

Reframing protection

[89] A separate branch of the Louisiana state government, the Office of Community Development (the state office responsible for administering disaster relief from the federal government), has actually developed a detailed manual for community adaptation that puts "managed retreat" front-and-center in Louisiana's planning for climate impacts, including encouraging the state to think about preparing "receiver communities" for those that migrate from the coast (LA SAFE, 2019). According to author interviews with numerous state officials, however, the plan has neither political backing from the legislature nor the Governor's office, so it remains to be seen to what extent its ideas are able to reorient the efforts of the CPRA.

Louisiana's vulnerabilities are the result of a complex set of factors and patterns of anthropogenic interventions spanning scales of time and space that defy easy policy solutions at the local level. As asserted in this paper, a logic of protecting existing economic gains has emerged as a default public policy position, even if incumbent activities simultaneously participate in processes of "unprotection." Public officials, in lieu of holding specific actors accountable, turn to sophisticated simulation exercises and "optimization" analyses to determine where and how money should be spent. This process works to depoliticize decision-making while also favoring protective actions that prop up current sources of public revenue, including extractive sources that exacerbate present and future vulnerabilities. Once protective investments are made (particularly large-scale investments), they can create infrastructural lock-in, making it harder to change course in the future (sunk costs invite more sunk costs). I call this overall situation the "treadmill of protection."

My conceptualization of ToP2 is framed heavily around the Louisiana case, yet similar dynamics of political economy are afoot elsewhere in the U.S. and other parts of the world. Fresh research already shows ToP2 at work in states and cities heavily dependent on tourism and property tax revenue linked to esthetically desirable, yet environmentally overburdened, urban areas. Major urban areas such as Boston, metro-Miami, New York, Venice, and Jakarta are all doubling down on expensive coastal infrastructure protections in recognition of risk, while also paradoxically encouraging additional coastal development to help maintain the tax base that pays for protection (Cohen, 2020; Samiolo, 2012; Taylor, 2020; Wakefield, 2019a; Colven 2017). Evoking the treadmill in all but name, one planning scholar writes in reference to Boston, "The trend of dense new developments along the coast is worrisome because it commits taxpayers to protecting these investments down the road—stressing the very budgets that town leaders and city planners hope to balance by building the developments in the first place" (Shi, 2020).

ToP2 dynamics are also present in other sectors, such as agriculture. In territories experiencing increasing water scarcity, for instance, where farming constituencies retain significant political clout, rural coalitions are able to exert pressure on public authorities to protect agricultural access to water supplies, even if it means expensive and potentially maladaptive irrigation infrastructure (Gaudin and Fernandez, 2018). The California Delta Conveyance Project, which aims to transport water at great cost from the Sacramento and San Joaquin River Deltas into Central Valley farmlands of California (Lakoff, 2016; Scoville, 2015), bears all the hallmarks of the treadmill. It would lock in status quo irrigation and cultivation practices for another decade or so, saving, at least temporarily, the Central Californian model of industrial food production. Protection, in each of these cases, essentially buys extra time for extraction, allowing incumbent economic actors to chase a final round of returns on existing investments, while delaying a deeper public reckoning with the social and environmental consequences of their activities.

Some aspects of ToP2, as conceived in this paper, are especially relevant to the U.S. context, such as the politics of federal disaster aid in Louisiana, or the protective reactions by local governments against threats to creditworthiness.[90] Yet these examples point to similar mechanisms elsewhere. Tools being developed to evaluate climate risks in U.S. municipal debt are already being promoted for scrutinizing risks in the sovereign bond market (BlackRock, 2019). Natural hazard-exposed

[90] It is true that U.S. states, municipalities and other local public entities have an unusual amount of authority in terms of self-financing urban and regional infrastructure by issuing debt. Few European cities, for instance, have anything resembling the same bonding powers (Cox, 2017). This accounts for why the U.S. makes up such a disproportionate part of the global municipal bond market (67%) (Cox, 2017).

developing countries may be pushed to divert multilateral loans toward "loss avoidance" protection efforts and away from economic development, making it harder to pay back borrowed money. South East Asian countries such as Myanmar and, the Philippines are considered particularly vulnerable in this regard (Volz et al., 2020). Other dimensions of ToP2 at work in developing countries deserve exploration, particularly in regions caught in what political economists call the "natural resource curse" (Ross, 2018; Sachs and Warner, 2001), where extractive industries dominate post-colonial politics. Elaborating these additional contexts will help further define the theoretical reach of the concept.

This paper is not arguing that governments should not spend money on adaptation. This money is already being spent, even if sometimes quietly (Koslov, 2019). What it hopes to encourage is additional research into the political economy of protection. Scholars need a better understanding of who benefits from public expenditures toward reducing vulnerability. Are local officials, national governments, and transnational actors actually working to redistribute risk fairly, or merely trying to defer losses and shelter private profits in the short-term? What kind of protection coalitions are already emergent in different territories? And what kind of accounting is necessary to understand the transfers of wealth involved in protection measures? Scholars also need to be primed for alternatives. Breaking out of treadmill tendencies in Louisiana likely means figuring out how to inhabit new coastlines, instead of preserving old ones. "Agricultural retreat," meanwhile, might look something like publicly assisting local farmers in shifting to new crops and adaptive farming practices, rather than maintaining water intensive modes of growing food.

The original treadmill of production analysts believe that a positive form of the environmental state can only be achieved through some form of de-industrialization. Getting off the treadmill of protection will require a similar restructuration of the role and use of public finance in the age of the Anthropocene as capital interests strive to squeeze one last cycle of profit out of past investments, while also gambling that they will not be the last ones left holding worthless properties and other sunk assets. Scholars need to move past the insight that protection for one group frequently means exacerbating vulnerabilities for others and begin articulating positive forms of adaptation premised on redistributing social and environmental vulnerability in a more equitable and even reparative fashion. Public authorities, meanwhile, should be called on to show how they are facilitating logics of protection that both mitigate the underlying drivers of the Anthropocene and reduce the exposure of already fragile populations, rather than gradually and repetitively enhancing both.

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Chapter 5

Conclusion

This dissertation was written in the model of a "three paper" dissertation, with each paper providing a separate but proximate analysis of a shared topic. If the classic dissertation monograph, to borrow a musical metaphor, is like a fugue, a unified exploration of a single musical idea, the three-paper dissertation is like an Extended Play (EP) record, with each chapter presenting departures and variations on a loose album theme. I nonetheless proposed, in the dissertation's introductory chapter, a theoretical frame for thinking about the connections between my cases. Each case, I argue, provides a glimpse into how knowledge about future risks of climate change is being turned into "actionable information" for guiding decision-making in the here-and-now. In this conclusion, I want to briefly summarize the linkages between the cases, review the concept of actionability, and point to the social implications and further directions for my research.

My three chapters provide insight into the conditions by which scientific knowledge gets transformed into "actionable information" and enrolled in processes of institutional governance. Actionability, in my cases, is about articulating knowledge and data produced by climate scientists with the particular processes of risk evaluation and risk management that administrative and economic actors use to assist in deciding whether to renew insurance contracts, how to plan for future water scarcity, and where to invest public money in protective infrastructure. In each of my cases, unintended consequences of actionability reveal an urgent need to develop new theories of institutional change that account for the field-level disruptions (and opportunities) that climate change is creating in social capacity for collective action.

Many physical consequences of climate change are already baked into the earth system, particularly for the next few decades (IPCC 2021). Whether these consequences end up being strenuously disruptive or completely catastrophic depends on the urgency with which societies began to reduce the use of fossil fuels and (increasingly necessary) begin successfully removing carbon dioxide out of the atmosphere. Yet even with the most aggressive actions, climate scientists anticipate a level of change that will reshuffle and shrink the distribution of some of life's essentials (i.e. food, water, and shelter) in different parts of the globe. As a result, climate change will sort groups at all levels of societies into new categories of winners and losers, with those already on the losing end of the socio-economic ladder likely to slide down even further.[91]

With the need to adapt to climate change an inevitable facet of how humans in every corner of the globe will experience the future, it is also necessary, I argue, to understand the social consequences of adaptation, especially deliberately planned adaptation. What is observed in my three cases is that a wide range of actors, from state agencies to local governments to corporations to citizen groups, are beginning to prepare for, or adapt, to these distributional climate effects. Processes of adaptation raise their own questions: How do the various ways by which these groups institutionalize knowledge about climate risks (for instance, into insurance underwriting, governance of water systems, and public financing of coastal protection) create

[91] Perhaps the idea of "winners" itself is no longer an appropriate descriptive category. As some scholars have already proposed, a sociology of climate change will largely be a "sociology of loss" (Elliott 2018). But within that loss, some will be devastating and disabling, while others will be entirely tolerable.

their own sorting effects? When climate knowledge is rendered actionable, what are the distributional consequences of that actionability? How does actionability produce path-dependencies and lock-in for how protective resources are spent, and what are ways to mitigate negative consequences of these processes? Efforts to reduce future pain are opening up a contentious and complex range of interactions around how knowledge about risks is mobilized for decision making and this is the nexus of issues that I bring to light in this dissertation.

As suggested in the introduction, actionability can be fit in a continuum with other social responses to climate change that have already been studied by sociologists. For instance, presented with information that the extraction and burning of fossil fuels are responsible for the bulk of climate change, organizations linked to these activities have sought to "institutionalize delay" of policies that would mitigate carbon emissions (and curtail their economic interests) (Brulle 2014; Jacques et al 2008; Farrell 2016). Efforts at delay have not completely inhibited other actors, such as governments, cities, companies or individuals from reducing emissions on their own, but it has created a broader "politics of denial" about climate knowledge that has, in many ways, successfully retarded the level of action that scientists insist is necessary to avert the worst consequences of climate change. At current rates of fossil-fuel consumption, as the latest report from the Intergovernmental Panel on Climate Change warns, the planet is on target to hit a world of 4.5 C warming by 2100, which would render the earth unrecognizable (IPCC 2021).

Actionability is the counterpoint of institutionalizing delay. Presented with information about the physical impacts of climate change, a growing range of social groups have largely accepted the forecasts and projections from climate models, and are working to figure out how to mitigate those impacts through preparedness measures.[92] These actors are making climate science "actionable" largely through piecemeal, localized struggles between groups of experts, affected communities and industry interests. The ways these different actors negotiate the distributional consequences of actionability engages what I call a "politics of anticipation". Many forms of deliberate actionability are directed at maintaining organizational functions in a way that also lessens future suffering and increases overall system resilience and adaptiveness.[93]

Yet actionability is not necessarily about the collective good. It can also lead to maintaining the status quo. The first two cases in the dissertation show how efforts to make climate science actionable create spillovers that engage a wide range or responses and reactions from actors affected by those efforts. These spillovers bring more concerns to the table, creating a messy form of adaptation pluralism that leads to incremental but substantive changes to systems of insurance underwriting and water allocation involving at least some level of input from affected actors. My third case, however, shows how processes of actionability can be captured by entrenched actors and lead to public investments in economic modes of private extraction that benefit very parochial interests while actually contribute to exacerbating vulnerabilities for other

[92] Actionable information bears a tight relation to cause and effect, in that a decision based on actionable information will prevent or achieve some recognizable outcome in relation to the action and whose benefits are, while perhaps not immediately felt, measurable within a time-frame of years and not decades. This is what makes mitigation activities less obviously "actionable" because mitigation aims to prevent the global heating of the planet by reducing parts per million of greenhouse gases in the atmosphere. The effects are so diffuse in both space and time that it is hard to experience, or associate the benefits of individual actions with their causes, except through intellectual effort.

[93] All of my cases look at deliberate forms and processes of actionability, but there can also be distributed, unplanned forms of actionability. Hino and Burke (2021) analyze how information about climate risk affects property value prices in US coastal states and find that, even in the absence of any kind of concerned or organized provision of information, a penalty has emerged for coastal properties as individual buyers begin taking new information about climate change into their purchasing decisions. Importantly, they note that coupling this bottom-up form of actionability with something more deliberate form of "communication about flood risk could help ensure such risk is appropriately reflected in market outcomes." (p1)

social groups – a dynamic I name the treadmill of protection. The political dynamics connected to anticipating future climate impacts will only become more pressing going forward as the pace and scale of global change quickens. There is great need for social analysts to study and learn from the early processes of adaptation to understand which institutional pathways lead to more equitable reductions in vulnerability and fairly distributed support for communities seeking to cope with future change.[94]

There is one more dimension of actionability, mentioned briefly in the introduction, that I want to raise here at the end as a direction for further study. There exists another use of the word actionable that has nothing to do with science and everything to do with the law. Whether something is legally "actionable" dictates whether that something can be categorized as meriting legal action. This is typically a civil or tort complaint under Common Law. Determining legal actionability is deciding whether an incident or problem that occurs between two parties falls under the purview of a court or not. Legal actionability is somewhat related to the question of legal standing, but much less formally defined. These two forms of actionability, the scientific and the legal, however, articulate with each other in interesting ways.

As climate science continues to gains in accuracy and legitimacy at producing nearer-term forecasts of impending change (i.e. improving in providing actionable information for decision making), whether action is taken or not on these forecasts may itself become grounds for legal

[94] There is obviously a strong historical dimension to actionability that deserves elaboration through future research. All of my cases cover events that occurred or were spurred by things that happened in the mid-2000s, when existing systems of governance were taxed by climatic events (Hurricane Katrina of 2005, the French Canicule of 2003). The socio-technical systems these events disturbed were themselves developed as responses to environmental events that occurred in the late 1980s and early 1990s (cat models after Hurricane Andrew in 1992; the MFT metrics after the extended drought of 1988,1989 and 1991 in the southwest of France; and the first large scale coastal restoration funding in Louisiana beginning with the Breaux Act of 1990).

actionability. For instance, if a city, which acknowledges in a public adaptation plan that it needs to expand storm water runoff capacity to deal with the rains from future storms, but does not implement its plan, this may create grounds for the city to be sued by insurers who suffer losses in subsequent flood events.[95] Or, as is currently happening, cities and other public jurisdictions around the globe are suing fossil fuel companies trying to hold them liable for the impacts of climate change in their communities. A suite of new climate change attribution and detection techniques are helping make extreme weather events legally "actionable" by assessing how much climate change enhanced these events' destructiveness, thus opening the door to assigning liability for that destruction to mitigation obstructing industrial actors. At the same time, actionable climate science may also limit previous categories of legal actionability. In the battles around whether coastal homeowners in California can build private seawalls or not (which negatively effects on beaches) the state's Coastal Commission is using climate projections to pit statutory authority (protection of public beaches) against homeowner's claims of constitutional authority (the taking of private property). Future work should consider how actionability is potentially co-produced as a category of scientific and legal knowledge and how they potentially reinforce each other.

[95] This kind of lawsuit is quite common in property and casualty insurance, and is called subrogation. When an insured client suffers a loss, the underwriter will pay out the claim, but then turn around and seek to recuperate their loss by identifying other actor(s) as the cause for the loss. Such a case has already happened (although later withdrawn) when Farmers Insurance sued the city of Chicago in 2014, after the Chicago area suffered three massive flood events within a span of five-years, for not implementing their adaptation plan.

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