Anticipatory Culture in the Bering Sea: Weather, Climate, and Temporal Dissonance

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(Manuscript received 16 April 2021, in final form 24 June 2021)

ABSTRACT: A major implication of climate change is the declining capacity for communities to anticipate future conditions and scenarios. In the Bering Sea region of western Alaska, this situation is acute and holds manifold consequences, particularly for the region's primarily Indigenous residents. Based upon interviews and fieldwork in two Bering Sea communities and among regional weather forecasters, this paper explores the intertwined temporalities of weather, climate, and social life. I demonstrate that *anticipatory culture*, which otherwise structures anticipatory practices with regard to climate, local weather, and social life, is beset by *temporal dissonance* across three time scales. First, dramatic climatic and ecosystem shifts reshape how Indigenous Peoples envision themselves as culturally inhabiting a long-range history and future. Second, changes in weather patterns, ecological cycles, and sea ice dynamics upset evaluations of seasonality, leading to a pervasive sense of unpredictability. Third, on the everyday time scale, social and technological change complicates mariners' evaluations of risk and economic (commercial and subsistence) decision-making. I conclude by connecting these three socioenvironmental temporalities to the temporal frames that primarily characterize weather and climate services, with an emphasis on the U.S. National Weather Service. The paper discusses how such services may further orient toward engaging socially embedded practices of anticipation in addition to formal prediction. Such an orientation can help to shape an anticipatory culture that more closely aligns meteorological and social patterns.

SIGNIFICANCE STATEMENT: Climate change alters how people anticipate the long-term future. For mariners and coastal communities in the Bering Sea region of Alaska, this situation is acute. Researchers and weather services have responded by generating predictive information. However, it is unclear how communities incorporate formal information in their everyday lives, decision-making, and evaluations of weather risk. This study therefore draws upon interviews and qualitative fieldwork in two Bering Sea communities to reconstruct how people anticipate future weather. The study finds that situations of dissonance—marked by unanticipated circumstances—exist at the generational, seasonal, and everyday time scales. I argue weather services can improve by moving beyond a paradigm of formal prediction to incorporate a deeper understanding of community-level social processes.

KEYWORDS: Arctic; Forecasting; Decision-making; Decision support; Indigenous knowledge; Seasonal effects; Societal impacts

1. Introduction

The Bering Sea is changing in unprecedented ways. Global warming is significantly altering the climate dynamics of the region, particularly by shifting seasonal sea ice and weather patterns, changing atmospheric and ocean temperatures, altering regional marine ecosystems, advancing ocean acidification, and changing nearshore dynamics including sea level rise, coastal erosion, and storm impacts (Marino 2012; Markon et al. 2018). Reduced seasonal sea ice extent has resulted in increased maritime shipping and activities in open ocean areas (Patel and Fountain 2017; Stevenson et al. 2019), while making nearshore travel and use of shorefast ice challenging (Gearheard et al. 2006; Druckenmiller et al. 2013). Climate change is projected to continue to alter coastal environments, ocean dynamics, and the character and geographic extent of the marine ecosystems upon which peoples' livelihoods depend (Brinkman et al. 2016; IPCC 2018; Wang et al. 2018; Meredith et al. 2019; Thoman et al. 2020b). Environmental change means that people in the Bering Sea region not only experience "new" weather, but also that they experience weather in new ways because of a larger social and ecological context marked by rapid, interrelated changes.

Within this socioenvironmental context, researchers and information services have responded by providing weather forecasts, climate projections, and "impact-based" services to help people effectively anticipate future risks (Harjanne 2017; Kettle et al. 2017; Jeuring et al. 2020; Thoman et al. 2020b; WMO 2021). However, as this literature recognizes, practices of prediction may not necessarily connect to the anticipatory practices that characterize marine and coastal communities. This paper presents analysis rooted in qualitative fieldwork primarily in two Bering Sea communities (Unalaska and Saint Paul Island) and among National Weather Service (NWS) forecasters in the region. By understanding practices of anticipation among mariners, I argue, information producers and communities can further develop a shared *anticipatory culture*. I define anticipatory culture (cf. Ahlqvist et al. 2012) as the symbols, practices, tools, and patterned ways through which a given social world answers the questions, "what is next?" and "now what?" This

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Publisher's Note: This article was revised on 9 August 2021 to include an additional affiliation for the author that was missing when originally published.

DOI: 10.1175/WCAS-D-21-0066.1

concept intentionally brings together processes and sites of information production, dissemination, and use and incorporates sociological concepts that concern how ideas about the future matter to social life and decision-making. Consider a weather forecast. Producing a weather forecast requires human forecasters to coordinate an array of instruments, assumptions, shorthand principles, training, experiences, and office culture that structures practices of prediction. Likewise, peoples' everyday anticipations of future weather draw upon a range of social interactions, rituals, and accumulated experiences with weather (and weather forecasts). Formal predictions and social anticipations may be variably coordinated with one another, and they may or may not correspond to actual experiences of weather. In this paper, I argue that the configuration of weather, climate, and social temporalities that presently structure anticipatory culture in the Bering Sea region is clearly beset by *temporal dissonance*. Temporal dissonance can be defined by struggles and negotiations that derive from new or uncertain answers to the two basic questions that mark anticipatory culture (What is next? Now what?). This paper empirically addresses anticipatory culture and temporal dissonance across multiple time scales.

Analysis of anticipatory culture has two major implications. First, it empirically builds a conceptual lens through which to understand the relationship between weather, climate, and social change. This may further social and physical science research at the intersection of weather risk and climate change. Second, it casts into relief the relationship between meteorological prediction and the social means by which people anticipate future weather. In other words, it does not reduce people to individual "users" of information. Unlike existing literature on the "co-production" of specific decision-support tools, this analysis hews more toward an understanding of social practices, thus clarifying the role of formal information for how people anticipate the future. As others have shown, the gulf between weather forecasts and human behavior remains wide (Morss et al. 2017). By relating social analysis of anticipatory culture to forecast practices and policy in a public weather service setting—in this case, NWS Alaska Region—this paper builds upon other cases to show how social science, community engagement, and weather prediction can continue to build effective services across the weather to climate time scale.

The paper proceeds as follows. First, I situate the case of the Bering Sea. Second, I present the theoretical basis of anticipatory culture, drawing from cultural sociology and science and technology studies. Third, I outline the method and data involved in this study. Fourth, I present results in three subsections, which demonstrate temporal dissonance across three respective time scales: the generational and climatic; the seasonal; and that of everyday decision-making that roughly corresponds to the time scale of forecast weather. Fifth, I discuss these findings by arguing weather services may further recognize how social temporalities intersect with the temporalities of weather and climate in a manner that is irreducible to the framework of prediction.

2. Background: Marine weather, climate, and risk in the Bering Sea

The Bering Sea marine and coastal environments feature extreme weather and consequential impacts that include fatalities and loss of property, land, and resources (Bell et al. 1990; Lincoln and Conway 1997; North Pacific Fishery Management Council 2017; National Transportation Safety Board 2018; Hovey 2020). Fisheries and marine activities are critical to many facets of Alaskan communities. The Bering Sea hosts among the most productive and economically significant fisheries in the United States and the world (Fissel 2021). Alaska waters seasonally feature hurricane force wind events and regular, significant storms (Mesquita et al. 2010; Pingree-Shippee et al. 2016). The harsh northern climate leads to distinct challenges when compared with those of midlatitudes: freezing spray, resulting in ice accretion and dangerous conditions on vessels, is the number one cause of fatalities, while sea ice significantly impacts access to ports, fisheries activities, and nearshore subsistence hunting and transportation.

NWS provides marine forecast services to mariners and coastal communities. Increasingly, NWS aims to improve "decision support services" (DSS) that more directly inform decision-making about weather risk. As a major priority at NWS and internationally, DSS involves incorporating social science into a traditionally physical-science-based domain of expertise (NWS 2013, 2018, 2019; Weaver et al. 2013; WMO 2015; Hobday et al. 2016; Kettle et al. 2017; Haavisto et al. 2020; Potter et al. 2021). The paradigm of DSS acknowledges that weather patterns and events vary in meteorological terms, but the context of decision-making regarding weather risk also depends upon social factors that lay outside the conventional boundaries of weather forecasting. Employing social science techniques to represent the full context in which people anticipate the future can thus improve upon the DSS paradigm.

Lessons on similar benefits can be found in related areas of expertise that have integrated social science, including as examples from the Alaskan context, developments in community-based fisheries ecology and coproduced climate science. In Alaska, fisheries social science is relatively well developed and informs fisheries governance (Carothers et al. 2012; Carothers 2015; Himes-Cornell and Hoelting 2015; Raymond-Yakoubian and Daniel 2018). Likewise, studies and programs have addressed climate change adaptation, including in the Bering Sea region (Cochran et al. 2013; Huntington et al. 2013; Robards et al. 2018; Manrique et al. 2018).

Given long-term uncertainty about climate, ecosystem, and economic changes in the Bering Sea, DSS may become more significant to Bering Sea communities than in the past. The rapidity of perceived and experienced changes in weather patterns, storm impacts, and sea ice dynamics mean that reliance upon traditional knowledge in the Arctic may increasingly upset communities' capacity to adapt their practices and knowledge to new conditions (Krupnik et al. 2010; Gearheard et al. 2010; Exchange for Local Observations and Knowledge in the Arctic 2019; Slats et al. 2019). As addressed by Indigenous communities, the problem of rapid environmental change is at once a matter of safety, livelihood, and the continuation of cultural practices reproduced through engagement with the environment (Maldonado et al. 2014; Willette et al. 2015). If traditional knowledge links weather to the holistic environment, then innovation in predictive information can support communities by relating Western scientific to traditional, especially Indigenous, knowledges (Pulsifer et al. 2012;

Manrique et al. 2018; Lovett et al. 2019; Alaska Arctic Observatory and Knowledge Hub 2019; Alaska Ocean Observing System 2020; Bahnke et al. 2020a,b). Representing the full context for anticipatory practices, as in this study, forms one component of the relationship between formal weather services and forms of knowledge that span the diversity of situations and cultures that characterize the region.

3. Anticipatory culture and temporal dissonance

Cultural sociologists have shown that practices of anticipation are a basic feature of pragmatic action across various social domains (Adam 1998; Mische 2009; Anderson 2010; Tavory and Eliasoph 2013). These scholars show that people make decisions based on how they imagine and represent the future. Other scholars have problematized practices of anticipation by investigating how weather and climate ''futures'' structure social action (Hall 2016), including among weather forecasters (Fine 2007; Daipha 2015), natural resource managers (Baker et al. 2018), and diverse communities facing compounded changes (Munshi et al. 2019; Callison 2020).

Climate change and weather patterns, scholars show, rarely ''determine'' social outcomes (Livingstone 2015). Rather, the relationship of society to weather and climate are modulated by cultural processes through which people make sense of ongoing experiences and construct visions of the future that can coordinate social action, identities, and cognition (Hulme 2016). Scholarship on these processes takes concepts of uncertainty, projection, contingency, and risk outside of the formal domains of science and policy (IPCC 2013; Lockie 2013). Representations of climate futures shape cultural bases of action—from social movements like Extinction Rebellion, which rest upon preapocalyptic discourse, to emotional and religious dealings with ''climate grief,'' loss, and hope, and to everyday engagement with weather (Elliott 2018; Butts and Adams 2020). The situation of many Indigenous Peoples puts in sharp relief how visions of the future intersect environmental change. Climate change disproportionately impacts Indigenous Peoples while compounding the social and environmental costs of colonialism to the maintenance of Indigenous cultures, livelihoods, and traditional knowledge (Whyte 2017; Chisholm Hatfield et al. 2018; Norgaard 2019).

More generally, if information shapes how people construct the future, then the process of using predictive information is fundamentally cultural. It relies upon rituals, learned practices, tacit understandings of what constitutes knowledge, and uses of and trust in technologies, representations, and information networks. Culture—whether the rationalized culture of a formal organization (such as weather forecast office) or that of communities—shapes decision-making processes and courses of action. Thus, how community members, on the one hand, and forecasters or science-based knowledge producers on the other, *coordinate* their anticipations of the future cannot be taken for granted. The concept of anticipatory culture provides a way to reconstruct disparate anticipations in order to improve upon the coordination among them. Shaping anticipatory culture, however, entails recognizing the temporal dissonance that may characterize communities and decision-making.

4. Method and data

This study is based on fieldwork in Unalaska, Alaska, in October 2019 and on Saint Paul Island, Alaska, from January through February 2020. The choice to study specific communities in relative depth is guided by Crate's (2011) approach called ''climate ethnography,'' which retools George Marcus' (1995) method of multisite ethnography by recognizing the relationship between geographically expansive patterns (such as environmental change) and local cultural circumstances. The timing of fieldwork was designed to correspond to major, weather- and climate-impacted marine-based activities in each location, including fishing seasons and the presence of Bering Sea storm events. Fieldwork among commercial fishermen was supplemented with interviews at the Pacific Marine Expo event in December 2019 in Seattle, Washington. Data collection in each site consisted primarily of conducting semistructured and in-depth interviews, observational research, participating in community meetings and events, and taking ethnographic fieldnotes.

This article is based on 39 primary informant interviews: 10 in Unalaska, 8 in Seattle, 18 in Saint Paul, and 3 in Anchorage. Interview participants included subsistence and commercial fishermen, subsistence marine hunters, commercial fish processing plant operators, and residents (Indigenous and non-Indigenous), elders, and community leaders. Examples of community leaders include local and tribal officials, emergency managers, and harbormasters. For reference, many commercial fisherman and crabbers who operate in the Bering Sea and were interviewed as part of this study are not residents but rather travel from mainland Alaska, Seattle, Washington, or elsewhere. Most Alaska Natives interviewed are Unangax̂ (Aleut) and are not representative of the full diversity of Bering Sea Indigenous communities. This study draws from an additional eight semistructured interviews with NWS meteorologists, supplemented with routine shadowing of operational weather and sea ice forecasting shifts at the Anchorage Weather Forecast Office and participation in NWS outreach activities. Interviews lasted between 12 min and 2.5 h, generally reflective of the different circumstances in which interviews were conducted, ranging from office spaces and community rooms to dockyards and on board vessels during severe weather. Most interviews were audio-recorded. Unrecorded interviews yielded detailed interview notes. All interview audio files and notes were transcribed by the author. Following transcription, I coded interview transcripts, ethnographic fieldnotes, and memos using Dedoose, a qualitative data analysis program (Dedoose 2018). Iterative open coding and memo writing were guided by the inductive analytic approach outlined by Emerson et al. (2011).

Some notes about interview notation are in order. To protect the confidentiality of research participants, individual-level identifiers are removed or replaced with pseudonyms. All interview excerpts are verbatim from interview transcripts or notes, including tonal notation, except for the removal of some explicit language, individual identifiers, and repetitive phrases that inhibit an accurate representation of the speaker's language. To simplify some quotations, ellipses remove repetitive or irrelevant words. Italics strictly denote speakers' tonal emphases. Brackets indicate either the speaker's use of words in a nonquoted statement or else added notation that clarify the speaker's intended meaning.

5. Results: Temporal dissonance over three time scales

This section presents findings on anticipatory culture and temporal dissonance across three time scales: first on the scale of generations, second on the scale of seasons, and third on the scale of everyday decision-making.

a. Climate change and generation-scale dissonance

The first finding about temporal dissonance comes primarily from the perspectives of Alaska Natives in the Bering Sea region. These perspectives demonstrate that climatic and ecosystem shifts complicate how people envision themselves as culturally inhabiting a long-range history and future.

The colonial legacy on the Aleutian and Pribilof Islands looms large for the region's Indigenous Peoples. Prior to Russian invasion, Indigenous groups had consistently occupied the Aleutian Islands for 8000–10 000 years (McCartney and Veltre 1999). Unalaska Island had been a major Unangan (Aleut) center, and by the end of the eighteenth century was an important hub for Russian (and later American) colonial activity for all of Alaska (Veniaminov 1840; Grinëv 2018). Anthropological research has estimated that the Aleutian Islands' Indigenous population was reduced by 75%–90% by colonial ecological violence and disease within 30 years of Russian contact in 1741 (Grinëv 2018, p. 113; Bacon 2019). Furthermore, Alaska Native cultures and languages were disrupted, and several marine mammal species were nearly hunted to extinction. Indigenous, marine-based cultures have long featured advanced boating, navigation, and hunting technologies, such that contemporary Unangan elders recognize lost knowledge and ways of living within the marine environment.

The Pribilof Islands (labeled by Russian founders as "Saint George" and "Saint Paul" Islands), over 200 miles north of Unalaska, held no stable settlement until Russian *promishleniki*, or fur hunters, arrived in the 1780s. They soon captured and brought Unangan people from Unalaska and nearby islands to serve as seal hunters and processors (Veltre and McCartney 2002; Grinëv 2018). When first opened to Russian colonial sealing, Saint Paul Island held an estimated four to six million northern fur seals, which migrate to the island's rookeries from spring to fall (Torrey 1983). Upon the sale of Alaska to the United States in 1867, the American Commercial Company ran the sealing operation as a monopoly for the U.S. Treasury Department, thus taking control of Unangan labor and livelihood on the Island, where Unangax̂ were formally wards of the state (Elliot 1906; Lee 1998). Competition for furs grew, and the population of the fur seals declined rapidly, while Unangax̂ gained few rights in the following decades under United States rule (Kohlhoff 1995; Torrey 1983; Reedy and Lowe 2017).

Unangan culture in the Pribilof Islands has been strongly but complexly tied to the fur seal, which for centuries has represented the means to life and subsistence but also the yoke of colonialism. Moreover, since the prohibition of the commercial seal harvest in 1983, the fur seal population initially rebounded but is now in steady decline because of rapid ocean ecosystem changes (Sidon and Zador 2019). Contemporary Unangax̂ nevertheless attribute prime cultural significance to the seasonal cycle of migration, arrival, mating, pupping, the subsistence harvest, and the departure of the seals. As one cultural leader of the Pribilof Islands stated, "if the fur seal is gone, our culture is also gone." For many residents, likewise, the colonial history and present precariousness of the fur seals reflect the socioecological uncertainty of the Pribilof Islands' cultural future [for comparison, in the case of Unalaska, see Sepez et al. (2007)]. Declining human population on the Islands, changing economic prospects, difficulty advancing native language literacy, climate, and ecosystem shifts—these changes register for some as a totality, rather than as separate issues.

Some Indigenous mariners thus lament the colonial experience as having erased cultural adaptations to the local marine environment. One fisherman and Unangan elder in Saint Paul reflected on "lost" knowledge about the Bering Sea:

> Unangan people had their ways [of knowing] weather. Tanya's husband is from Atka. And [looking to Tanya] like you told me, individuals studied clouds. And they used their skin boats, and they got their cloud readings. I've always called the Aleutians the 8000-year school, because that is how long the Unangan people lived, island hopping. The reading of the clouds, that is part of that, which was lost.

Upon reflecting on the meaning of lost knowledge, this individual proceeded to compare ancestral knowledge with the contemporary situation: "We are almost like *babies* now. It is a shame because we used to island hop all the way to Kodiak." As he explained, "Veniaminov, who wrote two centuries ago, told stories about how Unangan people made 14- or 16-hour voyages. *Of course* they had learned how to read the water."

Yet Indigenous mariners, who acknowledge dissonance about future marine-based livelihoods, also draw strength from the resilience that characterizes Indigenous history in the Bering Sea. For example, two halibut fishermen in Saint Paul discussed how they would fair if the halibut fishery, which they had transitioned into once the commercial seal industry closed, were to fail. As one concluded, "I don't know what St. Paul will *be* like without [the halibut fishery]. I mean, we are Aleuts, and Aleuts *survive*, but if we don't know what's next—and today that means if halibut fishing goes away—that makes me uncomfortable" (see also Weiss 2021). The uncertainty of the present expresses, for many, the temporal dissonance experienced by those who live in the light of a deep heritage and an unstable vision of how to secure, as the First Alaskans Institute (2017) proclaims, Indigenous "progress for the *next* 10 000 years."

To compare, others whom I interviewed operate in the Bering Sea with relatively minimal attention to longer-term future trends, and they place little significance on the historical context for their marine activities. Take for example many commercial crabbers and fishermen. Some reported that they have participated in the industry since childhood and described being part of multigenerational businesses. Mariners recognize environmental change, especially because the results of fisheries stock assessments structure the allocation of fishing quotas from season to season. Even so, commercial fishermen operating in the Bering Sea appear less concerned about climate change and its possible impacts on marine resources. Many viewed their operations as sustainable, insofar as the shorter time frame of the immediate future is the preeminent concern. Some fishermen expressed that government regulations ''over-manage'' their activities out of uninformed concern for environmental problems, including climate change. The sort of temporal dissonance that connects, for many Indigenous Peoples, the colonial history to long-term uncertainty about the future environment appears less relevant for nonresident commercial mariners. As explored below, however, temporal dissonance is hardly reducible to long-term concerns. At the scale of seasons and everyday weather, anticipatory culture in the Bering Sea is strained by overlapping sources of ''unpredictability.''

b. *''Everything is unpredictable'': Unanticipated seasonality*

Some mariners and residents believe that the Bering Sea features greater weather variability than in the past. For some patterns, including reduced precipitation falling as snow across the Aleutian and Pribilof Islands, seasonal changes are dramatic and obvious. One elder, who performs ecological monitoring and is also a subsistence hunter and fisherman, allowed me to accompany his rounds around the perimeter of Saint Paul: ''It shouldn't be like this,'' he said, pointing to a lack of snow on the roadside and gesturing out toward the tundra: ''We should have feet of snow.'' Others observe more dynamic changes, for example, shifts in the seasonality of southeasterly and north winds that strike Unalaska. Work is underway to bridge understandings of weather persistence and formal analyses (Gearheard et al. 2010; Weatherhead et al. 2010; Deemer et al. 2017), yet it is already clear that individuals register weather patterns within a general framework of what many discuss as an ''unpredictability'' that is difficult to partition into specific meteorological parameters.

The following example, drawn from an interview conducted by myself and an NWS meteorologist with Timothy, a mariner and a leader of the Qawalangin Tribe of Unalaska, shows how mariners register seasonal-scale changes as layers of a pervasive temporal dissonance:

> What I am concerned about is: what is *in store*? Looking at just the weather patterns, just from being raised here—from the seasons being so predictable in the 60s and 70s, [then] you saw more of a turbulent pattern. In the 80s, it seemed to warm up, [but] spring was *spring*, summer was *summer*, fall was *fall*, and winter was *winter*, and just repeat. It was so predictable to where you could feel it in your *blueprint*. And that is *gone*. Whatever is happening, it is at a summation point.

When asked about when he believed dramatic change commenced, Timothy responded,

> I think I would say 2008 to 2010, that was when I was not able to tell. And it is an *inner feeling*, it really is. Looking at last winter, you know, normally you're able to *tell*, being born and raised here, what the heck is what, and what is going to happen. You know, you can look *forward* to it.

Those whose experiences suggest dissonance about seasonal weather patterns frequently cited economic and livelihood concerns. For example, as Timothy continued,

> What *worries* me is our economy . . . we are ''pollock junkies,'' and even though the pollock biomass has grown 5000%, there is going to be a tipping point to some ecosystem, whether it is the phytoplankton or, what? How can you predict that? Everything seems so unpredictable. It goes against everything in somebody's blueprint, whether it is what you looked to in your traditional ecological knowledge, or just beginning downright confused.

The case above describes a common sense among residents that ecological and economic change overlaps with seasonal-scale weather, generating seasonal dissonance, a phenomenon documented among other Alaskan communities (Moerlein and Carothers 2012).

Although mariners generally face prospects of seasonal-scale shifts, commercial mariners generally acknowledge the cyclical, if not boom and bust, nature of Bering Sea commercial fisheries. As one result, mariners often vacillate between two positions that characterize the region's climate as either inherently unstable or as undergoing transformation. As one fisherman put it, on the one hand, ''We were wondering if global warming is making it windier . . . but the Bering Sea *is*, after all, the Bering Sea.'' On the other hand, this individual worried about ocean warming and the unknown ways marine mammals and commercial fish species may respond.

Despite a characterization of the Bering Sea as a simply extreme place, some mariners report operating in new locations because of changing ecological and seasonal conditions. Existing research on hunting, fishing, food processing, and marine transportation demonstrates that seasonal-scale changes have altered when and where people operate in the Bering Sea, western Alaska, and the Arctic (Johnson 2016; Loring et al. 2016; Struzik 2016; Markon et al. 2018; Thoman et al. 2020a). Climate projections indicate that novel weather patterns, seasonal sea ice coverage, and ecosystem changes make operational changes inevitable (Brown and Arrigo 2013; Labe et al. 2018a,b).

When seasonal-scale change results in mariners operating in novel environmental conditions, individuals and communities may lack relevant knowledge and experience, resulting in weather risk. Mariners report routinely drawing upon accumulated experiences, memories, short-hand principles, and traditions to inform decisions. In new places or circumstances, however, the capacity for people to integrate these resources into their anticipations of the future provides a shakier foundation for risk evaluation and decision-making. Two elders and boat captains on Saint Paul Island demonstrate a general pattern through which seasonal temporal dissonance leads to weather risk. As one explained, in the case of small-boat halibut fishing: "We like to fish shallow waters, generally under 20 fathoms, but temperature changes how we fish in the later part of the season. [Ocean] temperature peaks in September, but we think the fish are moving *sooner* now to colder, deeper water." Another captain, who has participated in the local halibut fishery since the 1980s, carried on this reasoning to indicate that September weather is much more uncertain, leading to greater weather risk combined with a less certain fish catch:

> [In] August, for us, it starts to get windy. That's when things shift. So, you really start to push after a while. You don't *want* to push, but you *have* to, based on the amount of quota left to catch. And you kind of get in a little panic mode . . . You are really starting to come up against the wall here, with the weather breaking. Come September, the weather here is not very [pause] *forgiving*, let me say it that way.

As a result of seasonal uncertainty, what this mariner describes as "panic mode" leads to situations of weather risk. More generally, oceanic and ecosystem change generates uncertainty with respect to the "fishing season(s)," which for many forms the basis for economic livelihood. As in other parts of Alaska, disruptions to seasonal rhythms present challenges to anticipating food availability and economic well-being. If people cannot rely upon subsistence activities, supplemented with reliable commercial ones, then peoples' local food security and livelihoods are at risk (Himes-Cornell and Hoelting 2015; Struzik 2016).

The most remarkable change that signifies, for Bering Sea residents, transformation in seasonality is the reduction or total loss of seasonal sea ice. An example of one tribal leader in Saint Paul expresses the general sentiment. Ralph had retired from fishing but maintains a leadership role in the subsistence seal hunts sponsored by the Aleut Community of Saint Paul. He attributed manifold changes in the region to sea ice loss: "We *need* the ice to come down." As he outlined, "the ice is what feeds the ocean;" it "protects the fish" (from overzealous fishermen, he indicated, smiling) and "refreshes the ocean," allowing the food web from plankton to marine birds, mammals, and humans to thrive—a principle supported, if complicated, by studies in marine ecology (Hunt et al. 2008; Brown and Arrigo 2013; Demuth 2019). Ralph spoke of the 2012 ice season with a sense of longing, as if his sense of security relied upon what he called "cycles" of ice that had yet to transpire. With winds shifting from the north and temperatures dropping during the time of our meeting, Ralph was hopeful that, although it had been years since pack ice reached the Pribilofs, the ice would soon return. Around the same time, an elder put this hope in context:

> Now people here feel the cold and treat it like it's a *good* thing. Before, the cold was a *bad* thing. Now it's a good sign. You feel those north winds blowing for several days. It's cold, and you *know* it's bringing the ice down. And what is it that [a local fisherman] tells us? Something like, "I know it's tough. Cold's *tough*—but it's good for the Bering Sea."

As the examples above demonstrate, marine communities connect livelihood strategies, weather-related decision-making, meaning, and security to seasonality. Anticipatory culture, however, is not only beset by climate- and seasonal-scale dissonance. Within an everyday time scale, as the following section explains, a changing informational environment around weather forecasts carries its own, distinct forms of dissonance that impact anticipatory culture among mariners and communities in the Bering Sea.

c. *Weather forecasts and everyday risk in a changing information environment*

Weather information shapes everyday decisions for marine-dependent operations. The salience of weather forecasts is difficult to overstate. A fishing fleet manager provides a common perspective:

> It's *every day* in Dutch Harbor [Unalaska]! [All present laugh] . . . If it's crab season or pollock season or cod season or halibut season . . . Weather is *always* a factor, which is why I always monitor it—in the morning, midday, evening. We know how fast it can change.

Similar statements abound among mariners, who intimately acknowledge how unforgiving Bering Sea weather can be, particularly when it is unanticipated.

The mariners on Saint Paul with whom I spent significant time routinely, if not religiously, gathered weather information. The interpretive process of retrieving and using weather forecasts is often social. Weather "talk" has been a feature of modern social life (Golinski 2003). Information, especially about the weather, circulates widely among fishing fleets and coastal communities. One fisherman in Saint Paul described how the local fleet tended to "congregate" in certain waters based on weather forecasts. Another fisherman characterized a common occurrence, in which mariners weigh their own decisions against fellow mariners, whom he jokingly characterized as "sheep" to signify the collective nature of marine decision-making:

> So, we will sit around the dock and bullshit. And we are like *sheep*, you know [laughing], and like we *all* go. Or you go out there, and then you find out, "Ah, it is too [expletive] to fish!" and then, maybe we will come back, and maybe somebody else will say, "No, we are *going*!" It comes down to that.

Beyond acting with a "herd" mentality, as described above, mariners more typically compare their own thinking with that of people they consider to be trustworthy peers who may inform critical decisions. As a basic example, one crab boat captain in Saint Paul, when asked how they interpret discrepancies between weather forecasts (in this case, NWS forecasts and Windy.com), stated that fellow fisherman formed the common denominator: "well, it's just—Call up your buddy and see what he's got going on—'hey what is going on over there?'" The social dimension of marine weather decision-making shapes how mariners gather, interpret, and respond to weather forecasts. However, the informational environment is rapidly changing in the marine community.

Technological change has long impacted both the production of weather forecasts and the ways people interpret weather information and thereby incorporate it into their lives and decisions (Sherman-Morris 2005; Henson 2010; Bostrom et al. 2015). Technological change among Alaskan marine and coastal communities is no exception. Most significant to this case is the recent rise of internet connectivity and associated forms of (mostly private, app-based) weather information. Such change has loosened a basic NWS monopoly on marine weather forecasting and given way to informational pluralism (cf. Allo 2007). In previous decades, radio broadcasts and weather fax charts, both disseminated by NWS, served as mariners' primary, if not exclusive, sources of marine weather information. As an initial example, one senior captain discussed what he termed the ''revolutionary change'' in how mariners have come to interact with weather information: ''we used to have to be like weathermen,'' he stated, suggesting that new, app-based forecasts may mean that mariners are either ''just getting dumber'' about interpreting weather, or else they have sufficient information and no longer need to be weather experts themselves.

When measured by routine frequency of use, the most common order of weather forecast sources that mariners reported are as follows: the ''Windy'' software application, followed by NWS products, other private apps, and finally word-of-mouth or direct communication. The following narrative, provided by a mariner in Saint Paul, demonstrates the basic pattern:

> I use Windy. [That is] just about it. I check the NOAA [NWS] weather occasionally, especially if I need something other than wind, because they show the ice and freezing spray, that kind of thing. I check that usually once a day. But, Windy is *really* nice. You can kind of just *see* what is going to happen.

Another mariner in Saint Paul follows the somewhat typical approach taken by open-ocean Bering Sea captains:

> We have Internet and, let's see, it is probably up right now. I use this one [opens the NWS Marine Zone text forecasts]. I am old school, so the text zone forecast. That is what I use as backup to *this*: Windy TY [opens Windy]. It's pretty nice. It is pretty darn accurate. We get some pretty good information, but I usually back it up. If I'm doing something critical, I will back it up [with] the NOAA zone forecast—Just to make sure.

The mariner went on to describe situations that demonstrated how multiple sources of information allowed him to assess vulnerability to weather hazards over a relatively large area and extended timeframe. The use of NWS forecasts as a ''backup'' source shows how multiple sources provides for informational synthesis, which in this case, among others, factors into a decision to do ''something critical.''

Synthesizing NWS and private weather services is the most typical method of using information to anticipate future weather. Yet experienced-based principles and what one mariner in Unalaska called ''mariners' folklore'' influence how mariners evaluate information sources. At times, mariners trust their own conclusions based on synthesizing information sources, even when faced with an official NWS warning. For example, one fisherman in Saint Paul stated that ''NOAA sends the weather report, which I can check twice a day, if I want to. And they tell you [the warning].'' However, he stated that he did not always receive warnings, but rather evaluated risk by other means. As he stated,

> For the most part, I don't know. Like, this [gesturing to graphic, app-based display on console] does not tell me if it is going to be ''heavy freezing spray'' [an NWS warning category] or not. But by seeing what the water is doing to the boat . . . Let's say I have a little glaze . . . and [mimicking checking the weather on console] ''oh shit, yeah, it is going to be cold!,'' and then . . . you *know* it is going to freeze!

In this case, the mariner described being guided by a synthesis of personal observation and interpretations of weather patterns displayed on a graphic-based weather app. When pressed about his ability to anticipate freezing spray, then, this individual relied upon an ingrained principle about storm directionality:

> Interviewer: Do you feel like you have a pretty good way of anticipating when you're going to hit freezing spray?
> Mariner: No, but as soon as I know it is going to come from the north, it is just freezing . . . Southerly, it is warmer. Easterly is cold, but not freezing. Westerly is not cold, but it brings big, big seas . . .But yeah, after doing that for many years, you kind of have an idea. Like I said, I can see what's coming.

The captain thus indicated that he trusts his own interpretation of multiple information sources, modulated by experience-based principles. This interpretive process helps to explain the seemingly contradictory position that he, on the one hand, cannot anticipate freezing spray conditions, but on the other hand, ''can see what's coming.''

Temporal dissonance arises most significantly when mariners engage a pluralistic information environment and attempt to decipher discrepancies between their own principles of decision-making and forecast *changes.* For context, most routine weather services issue deterministic forecast products, meaning they do not explicitly address uncertainty or probability of event occurrence. Instead, they collapse alternative possibilities into a given set of forecast values. Uncertainty is neither represented nor qualified, except within the NWS forecasters' area forecast discussion (provided regularly by Weather Forecast Offices) and auxiliary communications related to warning products or DSS.

Given deterministic representations of an uncertain future, many mariners distrust long-range information. Most mariners I interviewed place limited confidence in forecasts past three days. Yet the timeline of such ''faith,'' as one mariner put it, varies considerably. Rather than following strict rules with regard to forecast timeframes, most mariners gauge forecast uncertainty by working to interpret how different forecasts change when updated.

One fishing boat captain in Saint Paul demonstrates how this interpretive process works in practice:

> Captain: If I don't see any changes and it remains the same for two or three days . . . Today is, what? Friday? So that low is for Monday, and it has not changed since yesterday.
> Interviewer: So, you'll look at the update tomorrow...

Captain: Yes. So, it is a 50/50 chance it is going to be the same, or it is going to increase, you know? So that is my window. Like three days, four days. If I don't see radical changes, *then* I can plan ahead. And I have been using this [Time Zero, a private weather service] for three years now.[1] And we also can get the weather from NOAA. . . . It changes every six hours. *Or* it remains the same. For example, we were seeing this low coming, and it was *huge*—bringing *big* seas. The day before [the storm] was going to be 40 miles to the east. Overnight, it took a turn, and I was going to be right in the freaking *middle*. And I was going to get 40-foot seas, so I needed to *run*! It was like, ''[expletive] that, I'm out of here!''

As this narrative shows, mariners follow how forecasts change and respond to updated information. An updated near-term forecast, even if remarkably different, is generally considered to be trustworthy. Yet changes in longer-term forecasts generally decreased mariners' confidence.

A mariner in Unalaska demonstrates further how past experiences with forecast uncertainty, particularly with regard to extreme weather, shape future interpretations of forecasts:

When I see weird freaking scribbles on the three-day outlook, I place almost *zero* reliability on that, because it changes so fast. And I look at the [NWS] forecasts, and when you guys are changing it dramatically every six hours, I know I can just throw it out the window for any time after 24 hours. And that's just the nature of the beast. I mean, this is a violent place.

By monitoring changes in the forecast, this mariner has learned to distrust changes in forecast products, which to him indicate both an unpredictable system and uncertainty among forecasters in in the products they are issuing. Important, mariners' perspectives suggest a disconnect between forecasters' and users' interpretations of forecast changes. Although major forecast changes may represent higher confidence among forecasters, they may represent lower confidence to forecast users. It is difficult for mariners to interpret forecast changes insofar as the reasoning for such changes and its relationship to uncertainty is essentially opaque.

To act with uncertainty, mariners frequently report their own methods of anticipating future weather by adjusting forecasts to align with their experiences, local knowledge, or evaluations of the information sources that they regularly synthesize. The following example shows that the process of comparing information sources incorporates practices of ''bias correction'' of individual sources. Such practices depend on a mariner's past experiences and the weather dynamic they are seeking to identify, in this case, the timing of a storm passing. After identifying three information sources—Windy, Windfinder, and NWS—Ron, a resident halibut fisherman in Saint Paul, described:

I look at all of them, then compare. The trends are often close for all of them, but the timing can be different. I find Windy poor in the *timing* of wind, especially when it is going to come down after a storm. And that is important, because you're looking for when the storm will come down [to decide] when you can get out on the water.

A nonresident trawling boat captain in Saint Paul also demonstrates the common process, in this case calibrating wind and wave values projected by a web-based graphical forecast. The calibration process led him to evaluate that fishing in the conditions he anticipated would be too risky:

So, right now it says 5 knots [kt; 1 kt $\approx$ 0.51 m s^{-1}]. [But] it is kind of variable 10 [pause]. And I like this [graphical display] a lot better. I know that I have not updated. But it is going to be pretty nice, you know? And then this is the low that I'm talking about [pointing to screen]. So, if I put my cursor over it, it is saying 32 knots. Uh, it is going to be more like 45, you know? . . .When I see this, ''35 knots,'' it is a *no fishing* day for me. I am a small boat. And then it says 13-foot seas, but it is going to be more like 17, 18 [feet]. And they are going to be nine seconds apart. So, it is not going to be [expletive], but it will be uncomfortable [firm tone].

A kind of bias correction in this case allowed the mariner to make a critical decision by relating his experiences with his calibrated understanding of various forecast weather elements.

As demonstrated, mariners commonly adjust forecasts as they interpret them. To do so, they rely upon shorthand principles rooted in their own experiences with weather and with diverse information sources. Experiences with underforecast winds and seas leave special impressions upon mariners. Having dealt with unanticipated risks, previous experiences tend to inspire bias correction that incorporates caution and contingency into marine decision-making.

Experience and informational pluralism assist mariners in anticipating the future. Yet the idiosyncrasies of forecast interpretation, risk evaluation, and decision-making demonstrate that a common reference point through which various actors might coordinate their interpretations of the future is elusive. Undoubtedly this results in miscommunication, both between forecasters and forecast users and among mariners who wish to communicate with one another about anticipated weather. Further, weather risk remains a major aspect of Bering Sea fatalities, injuries, and damages.[2] The extent to which informational pluralism, and the resulting practices of synthesis and interpretation among mariners, results in a more or less coordinated anticipatory culture in the Bering Sea, remains to be seen. However, the changing informational environment, along with the seasonal- and climate-scale changes, suggests a need for researchers and weather services to reckon with the overlapping sources of temporal dissonance that mariners and marine communities presently face.

[1] Information on Time Zero's basic and subscription-based proprietary forecast products is available online (https://mytimezero.com/high-resolution-weather-forecasts).

[2] In response to the 2020 fatal sinking of the fishing vessel *Scandies Rose*, Bryce Buholm, a captain, testified: ''It's crab fishing in the Bering Sea. It's not safe. We do what we've got to do.'' [quoted in Hathaway (2021)].

6. Shaping anticipatory culture?

Using the lens provided by the concept of anticipatory culture, this study finds that socially structured anticipations of the future are upset across generational, seasonal, and everyday time scales. This study confirms other analyses that demonstrate significant social impacts of climate change and of shifting weather and ecological patterns in the Bering Sea and larger Arctic region (Carothers et al. 2012; Markon et al. 2018; Thoman et al. 2020b). Moreover, the analysis demonstrates that issues of anticipation are irreducible to a clear demand for predictive information. Ethnographic fieldwork and interviews centered in two southern Bering Sea communities may not yield findings generalizable to all Bering Sea communities, which are highly culturally diverse and face distinct environmental changes and weather risks (Huntington et al. 2013). Even so, analysis presented in this study allows for some general conclusions, particularly with regard to how weather services might incorporate social temporalities into decision support and related weather and climate programs. These conclusions about practices of what Tavory and Eliasoph (2013) label ''coordinating futures'' can likewise inform future research on anticipatory culture and the continued integration of social research into operational weather services (National Academies of Sciences, Engineering, and Medicine 2018).

In light of temporal dissonance, how might anticipatory culture be actively shaped? I will first address the issue of the changing informational environment, followed by discussion of seasonality and climate-scale dissonance, placing emphasis on opportunities for greater coordination among public weather services and communities.

The informational environment, analyzed above, has transformed how people gather, evaluate, and use weather information. This presents a situation for public weather services that may involve competition with other information providers as well as adaptation to user practices of information synthesis. NOAA/NWS may maintain weather data infrastructure, run weather models, and issue warnings that are incorporated into the entire weather forecast enterprise, yet NWS no longer holds a monopoly on weather prediction. The original validity of government weather prediction in the early-twentieth-century United States notably involved community-level relationships that established the credibility of government weather services (Pietruska 2011). Such relationships, then and now, take active work, outreach, and collaboration. The increasing use of private weather services notwithstanding, because many rural areas are underserved by such services, the function of public services remain critical. Yet to succeed, forecasting practices must be accompanied by a more comprehensive understanding of information users and the social, environmental, and informational systems that structure their activities and decisions.

Shaping how weather forecasters and communities anticipate seasonal-level patterns is inevitably difficult, given exogenous uncertainty around extended time scales. Yet, given the seasonal nature of activities in the Bering Sea, the case for coordinating weather services and community needs is both immediately practical and of general import to ''usable'' seasonal forecasts in various geographic and socioeconomic contexts [e.g., in the case of agriculture, see Hansen (2005), Crane et al. (2010), and Klemm and McPherson (2017)]. Beyond identifying key actors that can help to message extreme weather events and facilitate event-specific DSS, partnerships between forecast producers and communities, including in this case industry groups, local/tribal governments, and state and federal fisheries agencies, could be established to more deeply acknowledge the seasonal livelihoods and marine activities that characterize life on the Bering Sea. Forecast information could then be tailored, perhaps in a way that reduces risks associated with seasonal-scale temporal dissonance, as analyzed above.

Most activities in the Bering Sea are indeed seasonal, and the nature of decision-making and risk during specific seasons could benefit from tailored information services. A subsistence hunter and commercial fisherman in Saint Paul emphasized the importance of weather to the community, especially during the summer fishing months: ''For me, halibut fishing, our season normally starts in June and goes into September. And we check the weather every day. No matter who you are in the community.'' Coastal communities reliant upon specific subsistence resource ''seasons'' match the more itinerant or rotating pattern among commercial fishermen. In the southern Bering Sea communities studied, as in other Arctic communities, the seasonality of activity corresponds to certain weather patterns and different exposures to risk or productivity gains related to weather (e.g., with regard to sea ice seasons, see Eicken et al. 2014). The extent to which seasonal activities and risks are internalized within forecasters' practices is variable. Coordinating meteorological tools, including seasonal outlooks and long-range forecasts, with culturally structured seasonal activities is thus a direction of growth for public weather services (in this case, NWS). If developed, such services could strongly augment mariners' use of private weather services, which are hardly predicated upon a capacity to understand Alaskan communities.

On a longer time scale, climate change not only alters what constitutes ''normal'' weather and seasons, but also anticipations of ''normal'' social life and routine decision-making practices among mariners and coastal communities. Thus, a direction for strategic partnership among researchers and weather services is to further connect short- and long-term forecasts and projections. Another could be to engage Indigenous leaders in the coproduction of knowledge about weather and climate, recognizing that the organizational and scientific distinctions with regard to meteorological timeframes do not necessarily match those of communities. Such engagement could help information producers to secure partners that provide useful observational data while also advancing goals among Alaska Natives to reduce weather risk, enhance resilience, and support economic (subsistence and commercial) security. Some such projects are already underway in Alaska and Arctic regions (see, e.g., Arctic Research Consortium of the U.S. 2021; Alaska Native Tribal Health Consortium 2020), but few directly relate weather forecasts to projections of longer-term developments.

To conclude, it is worth recognizing that, over the past two centuries, weather prediction has had to adapt to novel social, environmental, and scientific/technical circumstances. In the process, public weather services have at times been overtly challenged by alternative bases of weather knowledge, including charismatic ''weather prophets,'' a public frustrated by poor information, and private firms that would make weather services into a market. The interplay of these forces has entailed challenges and opportunities for supporting a public informed about and prepared for future weather (Pietruska 2017; Baker 2020; Endfield 2021). In the past, to deal with these issues, innovations in public weather services have always entailed technical/scientific developments as well as concerted efforts to connect to communities. At a time when technological change is altering forecasting and forecast user practices, and when the anticipatory culture of the Bering Sea (and elsewhere) is beset by environmental, economic, and sociocultural change, it is necessary to consider how knowledge producers can best relate to the communities they serve.

Acknowledgments. This research was supported by the U.S. National Oceanic and Atmospheric Association (NOAA Grant NA16OAR4320115-91), the National Weather Service Alaska Region, and the University of Oklahoma Cooperative Institute for Mesoscale Meteorological Studies. I acknowledge the gracious time and insights provided by all who participated in this study. I also acknowledge guidance provided by Eugene Petrescu, Louise Fode, Donald Moore, Jason Aschenmacher, Emily Niebuhr, Lauren Divine, Amos Philemonoff, Aquilina Lestenkof and to forums provided by the American Geophysical Union, American Meteorological Society, American Sociological Association, National Weather Service, and Sea Ice Prediction Network.

Data availability statement. Data collection and analysis for this project has been granted exempt status and is governed by the University of Oklahoma Institutional Review Board for the Protection of Human Subjects (IRB 9767). In accordance with IRB protocol, data including human subject identifiers is confidential. The author can provide limited access to anonymized data and relevant research materials upon request.

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