Check for updates

Article

Progress in Human Geography
2016, Vol. 40(6) 770–793
© The Author(s) 2016
Reprints and permission:
sagepub.co.uk/journalsPermissions.nav
DOI: 10.1177/0309132515623368
phg.sagepub.com
SAGE

Glaciers, gender, and science: A feminist glaciology framework for global environmental change research

Mark Carey, M. Jackson, Alessandro Antonello and Jaclyn Rushing
University of Oregon, USA

Abstract
Glaciers are key icons of climate change and global environmental change. However, the relationships among gender, science, and glaciers – particularly related to epistemological questions about the production of glaciological knowledge – remain understudied. This paper thus proposes a feminist glaciology framework with four key components: 1) knowledge producers; (2) gendered science and knowledge; (3) systems of scientific domination; and (4) alternative representations of glaciers. Merging feminist postcolonial science studies and feminist political ecology, the feminist glaciology framework generates robust analysis of gender, power, and epistemologies in dynamic social-ecological systems, thereby leading to more just and equitable science and human-ice interactions.

Keywords
feminist glaciology, feminist political ecology, feminist postcolonial science studies, folk glaciology, glacier impacts, glaciers and society

I Introduction

Glaciers are icons of global climate change, with common representations stripping them of social and cultural contexts to portray ice as simplified climate change yardsticks and thermometers. In geophysicist Henry Pollack's articulation, 'Ice asks no questions, presents no arguments, reads no newspapers, listens to no debates. It is not burdened by ideology and carries no political baggage as it crosses the threshold from solid to liquid. It just melts' (Pollack, 2009: 114). This perspective appears consistently in public discourse, from media to the Intergovernmental Panel on Climate Change (IPCC). But the 'ice is just ice' conceptualization contrasts sharply with conclusions by researchers such as Cruikshank (2005), who asks if glaciers listen, Orlove et al. (2008b), who analyze the cultural framing of glaciers, Carey (2007), who sees an endangered species narrative applied to glaciers, Jackson (2015), who exposes how glaciers are depicted as ruins, and Sörlin (2015), who refers to the present as a cryo-historical moment because 'ice has become historical, i.e. that ice is an element of change and thus something that can be considered as part of society and of societal concern' (Sörlin, 2015: 327).

Corresponding author:
Mark Carey, Robert D. Clark Honors College, University of Oregon, Eugene, OR 97403, USA.
Email: carey@uoregon.edu

Nüsser and Baghel (2014) also reject the 'ice is just ice' assertion. Glaciers, they argue, 'have increasingly become contested and controversial objects of knowledge, susceptible to cultural framings as both dangerous and endangered landscapes' (Nüsser and Baghel, 2014: 138). Glaciers, after all, affect people worldwide by influencing sea level, providing water for drinking and agriculture, generating hydroelectric energy from glacier runoff, triggering natural disasters, yielding rich climate data from ice cores, shaping religious beliefs and cultural values, constituting identities, inspiring art and literature, and driving tourist economies that affect local populations and travelers alike (e.g. Carey, 2010; Cruikshank, 2005; Gosnell, 2005; Hewitt, 2014c; Orlove et al., 2008a). Despite their perceived remoteness, glaciers are central sites – often contested and multifaceted – experiencing the effects of global change, where science, policy, knowledge, and society interact in dynamic social-ecological systems. Today, there is a need for a much more profound analysis of societies living in and engaging with mountains and cold regions (Halvorson, 2002; Byers and Sainju, 1994; Bloom et al., 2008), including the social, economic, political, cultural, epistemological, and religious aspects of glaciers (see e.g. Allison, 2015; Gagné et al., 2014).

A critical but overlooked aspect of the human dimensions of glaciers and global change research is the relationship between gender and glaciers. While there has been relatively little research on gender and global environmental change in general (Moosa and Tuana, 2014; Arora-Jonsson, 2011), there is even less from a feminist perspective that focuses on gender (understood here not as a male/female binary, but as a range of personal and social possibilities) and also on power, justice, inequality, and knowledge production in the context of ice, glacier change, and glaciology (exceptions are Bloom et al., 2008; Williams and Golovnev, 2015; Hevly, 1996; Hulbe et al., 2010; Cruikshank, 2005). Feminist theories and critical epistemologies – especially feminist political ecology and feminist postcolonial science studies – open up new perspectives and analyses of the history of glaciological knowledge. Researchers in feminist political ecology and feminist geography (e.g. Sultana, 2014; Mollett and Faria, 2013; Elmhirst, 2011; Coddington, 2015) have also called for studies to move 'beyond gender', to include analyses of power, justice, and knowledge production as well as 'to unsettle and challenge dominant assumptions' that are often embedded in Eurocentric knowledges (Harris, 2015: xx). Given the prominent place of glaciers both within the social imaginary of climate change and in global environmental change research, a feminist approach has important present-day relevance for understanding the dynamic relationship between people and ice – what Nüsser and Baghel (2015) refer to as the cryoscape.

Through a review and synthesis of a multi-disciplinary and wide-ranging literature on human-ice relations, this paper proposes a *feminist glaciology* framework to analyze human-glacier dynamics, glacier narratives and discourse, and claims to credibility and authority of glaciological knowledge through the lens of feminist studies. As a point of departure, we use 'glaciology' in an encompassing sense that exceeds the immediate scientific meanings of the label, much as feminist critiques of geography, for example, have expanded what it is that 'geography' might mean vis-à-vis geographic knowledge (Domosh, 1991; Rose, 1993). As such, feminist glaciology has four aspects: (1) *knowledge producers*, to decipher how gender affects the individuals producing glacier-related knowledges; (2) *gendered science and knowledge*, to address how glacier science, perceptions, and claims to credibility are gendered; (3) *systems of scientific domination*, to analyze how power, domination, colonialism, and control – undergirded by and coincident with masculinist ideologies – have shaped glacier-related

sciences and knowledges over time; and (4) *alternative representations*, to illustrate diverse methods and ways – beyond the natural sciences and including what we refer to as 'folk glaciologies' – to portray glaciers and integrate counter-narratives into broader conceptions of the cryosphere. These four components of feminist glaciology not only help to critically uncover the under-examined history of glaciological knowledge and glacier-related sciences prominent in today's climate change discussions. The framework also has important implications for understanding vulnerability, adaptation, and resilience – all central themes in global environmental change research and decision-making that have lacked such robust analysis of epistemologies and knowledge production (Conway et al., 2014; Castree et al., 2014).

II Why feminist glaciology?

Feminist glaciology asks how knowledge related to glaciers is produced, circulated, and gains credibility and authority across time and space. It simultaneously brings to the forefront glacier knowledge that has been marginalized or deemed 'outside' of traditional glaciology. It asks how glaciers came to be meaningful and significant (through what ontological and epistemological process), as well as trying to destabilize underlying assumptions about ice and environment through the dismantling of a host of boundaries and binaries. The feminist lens is crucial given the historical marginalization of women, the importance of gender in glacier-related knowledges, and the ways in which systems of colonialism, imperialism, and patriarchy co-constituted gendered science. Additionally, the feminist perspective seeks to uncover and embrace marginalized knowledges and alternative narratives, which are increasingly needed for effective global environmental change research, including glaciology (Castree et al., 2014; Hulme, 2011). A combination of feminist postcolonial science studies and feminist political ecology provide the intellectual foundation for feminist glaciology.

Most existing glaciological research – and hence discourse and discussions about cryospheric change – stems from information produced by men, about men, with manly characteristics, and within masculinist discourses. These characteristics apply to scientific disciplines beyond glaciology; there is an explicit need to uncover the role of women in the history of science and technology, while also exposing processes for excluding women from science and technology (Phillips and Phillips, 2010; Domosh, 1991; Rose, 1993). Harding (2009) explains that the absence of women in science critically shapes 'the selection of scientific problems, hypotheses to be tested, what constituted relevant data to be collected, how it was collected and interpreted, the dissemination and consequences of the results of research, and who was credited with the scientific and technological work' (Harding, 2009: 408). Scientific studies themselves can also be gendered, especially when credibility is attributed to research produced through typically masculinist activities or manly characteristics, such as heroism, risk, conquests, strength, self-sufficiency, and exploration (Terrall, 1998). The tendency to exclude women and emphasize masculinity thus has far-reaching effects on science and knowledge, including glaciology and glacier-related knowledges.

Feminist glaciology is rooted in, and combines, both feminist science studies and postcolonial science studies to meaningfully shift present-day glacier and ice sciences. While feminist science studies focuses explicitly on gender and the place (or absence) of women in science, it can neglect specific analyses of the social relations of colonialism and imperialism, emphasizing instead Western women without sustained attention to indigenous, non-Western, and local knowledge systems that are the centerpiece of postcolonial science studies (Harding,

2009; Phillips and Phillips, 2010; Schnabel, 2014). The postcolonial perspective is crucial for understanding glaciological knowledges because the science of glaciology has historically participated in the imperialist, colonial, and capitalist projects associated with polar exploration, mountain colonization, resource extraction, and Cold War and other geopolitical endeavors.

More recently, glaciology has also been central to earth systems science that often relies on remote sensing from satellite imagery to suggest broader claims of objectivity but is actually akin to the 'god trick of seeing everything from nowhere' (Haraway, 1988: 581; also see Shapin, 1998). Questions about epistemology in climate science, ice coring, and glaciology are only beginning to be asked, especially focusing on Cold War polar glaciology (Martin-Nielsen, 2012, 2013; Elzinga, 2009; Korsmo, 2010; Naylor et al., 2008; Turchetti et al., 2008; Macdougall, 2004; Finnegan, 2004; Heymann et al., 2010; Bowen, 2005; Hulme, 2010). Of these studies probing the discipline of glaciology, only a tiny subset analyze gender (exceptions include Bloom, 1993; Bloom et al., 2008; Hulbe et al., 2010; Hevly, 1996) or approach human-glacier interactions from the perspective of feminist postcolonial science studies or feminist political ecology (exceptions include Williams and Golovnev, 2015; Cruikshank, 2005). Fewer still recognize indigenous knowledges, local perspectives, or alternative narratives of glaciers, even though large populations of non-Western and indigenous peoples inhabit mountain and cold regions near glaciers and possess important knowledge about cryoscapes (Carey et al., 2015; Nüsser and Baghel, 2014; Drew, 2012).

Feminist and postcolonial theories enrich and complement each other by showing how gender and colonialism are co-constituted, as well as how both women and indigenous peoples have been marginalized historically (Schnabel, 2014). Feminist glaciology builds from feminist postcolonial science studies, analyzing not only gender dynamics and situated knowledges, but also alternative knowledges and folk glaciologies that are generally marginalized through colonialism, imperialism, inequality, unequal power relations, patriarchy, and the domination of Western science (Harding, 2009).

An additional theoretical foundation for feminist glaciology is feminist political ecology, which has generally emphasized unequal vulnerability and disproportionate global change impacts, but which also contributes significant research on knowledge production, ontologies, and epistemologies. With hundreds of millions of people utilizing glaciers for everything from drinking water and hydroelectricity to recreation and spiritual sites, the disproportionate vulnerabilities and disparate adaptive capacities in these societies are critical to acknowledge. Feminist political ecology addresses how inequality and unequal power relations – mediated and co-constituted through gender dynamics – have silenced the knowledge of people 'most affected and marginalized by neoliberal, colonial, and patriarchal systems' (Hanson and Buechler, 2015: 6).

Crucially for feminist glaciology, feminist political ecology argues for the integration of alternative ways of knowing, beyond diverse women's knowledges to include – more broadly – the unsettling of Eurocentric knowledges, the questioning of dominant assumptions, and the diversification of modes and methods of knowledge production through the incorporation of everyday lived experiences, storytelling, narrative, and visual methods (Harris, 2015). This inclusion of alternative knowledges and narratives alongside analysis of colonialism and inequality, such as race relations (Mollett and Faria, 2013), fits squarely into more recent feminist political ecologies that increasingly go 'beyond gender'. This means that the research builds on 'a history of boundary-breaking ideas [that] makes possible the present-day spaces where feminist geographers explore power,

justice, and knowledge production, ideas that encompass but also surpass a focus on gender' (Coddington, 2015: 215).

Feminist glaciology raises critical conceptual, analytical, and epistemological questions that are largely absent in the 21st-century love affair with glaciers and ice. The framework offered here strives to open discussions, to introduce avenues of investigation, and to suggest ways forward not only for scientific enquiry that includes the environmental humanities and social sciences, but also for public perceptions of glaciers. Examples within this review and synthesis article are primarily meant to expose the value and various dimensions of the feminist glaciology framework; they are not meant to be comprehensive, but rather starting points to indicate lines of future investigation into this major gap in glacier studies and its related contribution to global environmental change research and both human and physical geography.

III Knowledge producers

Since the origins of the field of glaciology in the 19th century, the discipline has been dominated by men and masculinity. Glaciology, polar exploration, and mountaineering – profoundly interconnected pursuits – have also been characterized by masculinist discourses that privileged manly exertion, heroism, and conquest (Chisholm, 2008; Schrepfer, 2005; Bloom, 1993; Brown, 2002). In polar sciences and Antarctica in particular, women were marginalized and absent until at least the mid-20th century (Pyne, 1986; Fogg, 1992), while a white, masculinist narrative emerged instead (Bloom, 1993; Bloom et al., 2008; Lewander, 2009). Women, if mentioned at all, were often cast as men's curiosities or companions, as wives or helpers (Hulbe et al., 2010). Their appearance was almost always incidental to the aims of men and the male ship captains, expedition leaders, and government officials. As just one example, Louise Séguin sailed secretly on Captain Yves Joseph de Kerguelen's 1773 voyage to the Antarctic region (Lewander, 2009: 92). She made scientific observations and discoveries but, at first, hid from public visibility. Subsequent publicity about her presence tarnished Kerguelen's reputation and contributions, thereby demonstrating not only how women's roles and activities have been eclipsed but also how discovery and exploration were supposed to be men's terrain. National exploration, scientific practices, and patriarchy all resulted in the exclusion of women and the restriction of glaciological (and other) knowledge.

Of course women were not entirely absent from glaciology and related disciplines and activities. Fanny Bullock Workman, a famous mountaineer who also studied glaciers in the early 20th century, and Mary Morris Walcott, who photographed and measured glaciers in the Canadian Rockies in the late 19th and early 20th century, represent exceptions to the male-dominated discipline of glaciology. In fact, Workman was part of a larger group of early-20th-century women – such as Annie Smith Peck, who logged many first ascents and set elevation records in South America – who climbed mountains to make a case for women's suffrage and gender equality in the United States (Blum, 1980; Miller, 1984; Ellis, 2001; Peck, 1911); there are also significant examples in Europe, such as Fanny Copeland (Clarke and Anteric, 2011). In mountaineering, however, men continued to be more numerous than women worldwide, even though an increasing number of women have been climbing peaks and doing glaciological research, especially since the 1970s (Blum, 1980; Frohlick, 1999–2000; Miller, 1984; Logan, 2006; Maddrell, 2009). Nevertheless, it should be noted that neither masculinity nor the social construction of mountaineering have remained static over time. It is important to probe the nuances of gender within each place and period under consideration to avoid simplistic male-female

binaries or fixed views of gender, glaciers, and mountaineering (Frohlick, 1999–2000).

Both male-dominated glaciology and masculinist narratives about glacier knowledge production have persisted despite the slowly increasing participation of women in glaciology since the 1970s. When women did begin working in Antarctica, media commentary and reporting often portrayed them as 'girls' who were 'invading' male terrain (Burns, 2000; see also Chipman, 1986). A leading science journalist of his time, Walter Sullivan (1969) of the *New York Times*, described the first all-women scientific expedition to Antarctica in 1969 as 'an incursion of females' into 'the largest male sanctuary remaining on this planet'. Another article on this expedition speculated about the women's potential 'loneliness' or 'the possibility of running into a mad seal' (Jordan, 1969), whereas a contemporaneous report of men's work was headlined 'Antarctica: Men Risk Death to Unlock its Awesome Secrets' (Laine, 1970). While men had agency and control over their fate, women were at the mercy of their emotions and treacherous nature. The British were especially slow to support female scientists in Antarctica, not allowing women to join summer research expeditions until the early 1980s and finally to over-winter until the early 1990s. The British experience is especially noteworthy because the glaciologist Elizabeth Morris was appointed Head of the Earth Sciences Division of the British Antarctic Survey (BAS) *before* she became the first woman to join a BAS field team in Antarctica in 1987 (Hulbe et al., 2010). Norwegian Polar Institute glaciologist Elisabeth Isaksson expresses her dismay about that 1987 expedition, recalling that Morris 'had to talk to all of the researchers' wives and ensure them that she would not hit on their husbands'. Isaksson explains that 'it's like you think you're hearing it wrong, that we're talking about 1887 and not 1987' (Aukland, 2014).

Marked shifts in women's roles in glaciology and polar research occurred during the 1980s, reversing longstanding trends. Though women began publishing in the *Journal of Glaciology* and the *Annals of Glaciology* soon after the journals emerged in the late 1940s (e.g. Owston and Lonsdale, 1948), they only accounted for one or two articles a year, and many years had no female authors in either journal. Those numbers rose from 10 women in total publishing in the two journals in 1979 to 55 women in 1990, though there was another dip in numbers in the early 1990s, until a steady increase to the present (Hulbe et al., 2010). Despite significant progress for women in glaciology since 1979, women in 2009 still represented less than 20 percent of authors in these two flagship glaciology journals (Hulbe et al., 2010). In terms of grant recipients and principal investigators, 24 percent of PIs or co-PIs on US National Science Foundation Office of Polar Programs in the period of the 4th International Polar Year (2007–9) were women, up only from 18 percent in 1997–9 (National Research Council, 2012). The male-dominated landscape is not confined to science and exploration: men dominate in Arctic literature as well. Of the 1945 works of literature on the Arctic and northern regions that are part of the International Laboratory of the Comparative Multidisciplinary Study of Representation of the North at the Université du Québec in Montreal, only 401 were authored by women, which represents about 20 percent – the same percentage of female characters in these books (Chartier, 2008).

Measuring women's involvement by tracking their published literature or other similar metrics risks recognizing women in glaciology only if they behave like men or do the things that men do, such as earning a PhD in a university where men hold the majority of leadership and faculty positions, or publishing in peer-reviewed journals often managed by men. It also ignores the preponderance of sexual harassment and sexual assault by field scientists in other disciplines, especially at early career stages. Clancy et al. (2014) sampled 666 researchers in

other science fields to find that 64 percent of women reported they had experienced sexual harassment, while more than 20 percent revealed they had experienced sexual assault. Women were 3.5 times more likely to experience harassment than men, indicating its gendered nature. While the Clancy et al. (2014) study is not about glaciology field work or the experiences of female glaciologists per se, it illuminates trends in these other fieldwork-focused disciplines to suggest that analyzing only the numbers of participating women in glaciology may obscure many other aspects of gender discrimination in glaciology.

To balance out the male-dominated world of glaciology, unique programs such as 'Girls on Ice' seek to provide glaciology (and life) training for high-school-aged young women in field schools in Alaska and Washington state. This program offers an alternative to the more traditional path to a career in glaciology or any field as it specifically focuses on empowering women through their experiences with and research about glaciers. While the program may perpetuate a male-female binary that feminist studies and queer theory have long sought to dismantle, Girls on Ice plays a key role in glaciology to provide female role models, to understand glaciers in unique experiential ways, to imbue teenage women with the confidence to become scientists and community leaders, and to inspire them about learning science (Pettit et al., 2010). The program's founder, Erin Pettit, maintains that it is essential to restrict Girls on Ice solely to young women:

> This is a course to get dirty, wear clothing or harnesses and helmets that are not necessarily the most beautiful or flattering. Our society has taught girls not to like any of those things, and to not show their interest or intelligence in science. But I want to provide a space without that pressure – where the girls can show their interest, their intelligence, their strength. Then when they get back home, hopefully they will feel a bit less constrained (quoted in Bolen, 2006).

Participants confirm the importance of an all-women team, noting in particular the benefits of female scientist role models (Wertheim, 2005; also see http://girlsonice.org/category/reflections/). These experiences and insights are critical for women in a field in which men typically run the graduate programs, edit the journals, and peer review the majority of papers (Hulbe et al., 2010).

Local, non-Western, and indigenous societies are often no more egalitarian than scientific disciplines such as glaciology, and thus they, too, experience differential representation in the production of environmental knowledges (Cochrane, 2014). Klein et al. (2014) report in their study of Tibetan herders' understandings and observations of climate change, for example, that bias and inequality exist in those communities in Nagchu Prefecture. It was not possible to achieve gender balance in their interviews, for instance, because women repeatedly refused to be interviewed, citing their own lack of knowledge and illustrating how dominant perceptions of 'glaciology' can emerge, which may in some cases suppress alternative knowledges. Women often do possess different knowledge about glaciers due to many issues, such as: spending more time than men attending to livestock near Andean glaciers (Dunbar and Medina Marcos, 2012); managing agriculture, terracing, and irrigation that includes the distribution of glacier runoff in highland Peruvian communities (Bolin, 2009); being responsible for mobility, storage, and shelter amidst changes to snowfall and other cryospheric changes on the Tibetan Plateau (Yeh et al., 2014); expressing water supplies in the Ganges River through spiritual frameworks that contradict hydrologic models (Drew, 2012); and responding to diminishing water supplies in Tajikistan mountains with more efficient water use practices, as opposed to men's reactions to emigrate from their communities (Christmann and Aw-Hassan, 2015). Nevertheless, it is critical to avoid objectifying women's vulnerability, clinging to a

sharp male-female binary, or portraying women as passive victims. After all, climate change can lead to the breakdown of stereotypical gender roles and even 'gender renegotiation' (Godden, 2013). Moreover, the romanticization of women's environmental sensibilities or the over-classification of women as poverty-stricken and marginalized in local communities can render them passive; such representations often privilege environmental forces – such as climate, glaciers, drought, or hydrology – acting on women, without sufficient analysis of power relations and inequalities that more profoundly affect vulnerability and knowledge disparities (Arora-Jonsson, 2011).

One way to diversify knowledge production and collect environmental knowledge from local women is through emerging methodologies, such as locally-led indigenous ethnographic video (audio-visual storytelling) among women in the Pamir Mountains of Tajikistan (Williams and Golovnev, 2015). This project's goal was to examine how local indigenous assessments of climate change and glacier shrinkage corresponded with scientific, governmental, and NGO conclusions. Team leaders specifically sought women's voices and contributions after recognizing that women generally did not hold public positions of authority. Ultimately the video production process not only involved local women in three communities, but also went beyond participation to achieve active collaboration in both the video creation and the collection of climate- and glacier-related knowledge. Knowledge about changing climatic conditions and glaciers varied among the women involved, with one participant appreciating the warmer weather at high elevation, another lamenting the loss of a glacial lake for its hydrologic impacts, and another who inhabited an urban area being largely unfamiliar with nearby environmental changes.

Including these divergent local voices and perspectives diversifies (and localizes) the information produced in national climate assessments and underscores the disconnect between local women's knowledge and Western scientific conclusions expressed in the IPCC and elsewhere. Williams and Golovnev believe this is vital to illustrate, given the ways in which policy is too often based solely on Western science. 'The Western climate science-to-policy paradigm', they conclude, 'paralyzes public agency through elitist mechanistic science, market-driven governance decisions, and globally dominant consumer skewed media network products. This approach to environmental governance is oppressive for peoples with different cultural configurations' (Williams and Golovnev, 2015: 220). Involving local indigenous women – or any marginalized groups – facilitates equality and self-determination while simultaneously producing more equitable discussions about the cryoscape, climate, and global environmental change.

IV Gendered science and knowledge

The history of glaciology is not simply about the ubiquity of men and the absence and/or erasure of women. It is also about how scientific practices and results are gendered. Many natural science fields have historically been defined by, and their credibility built upon, manly attributes such as heroic (often nationalistic) exploration and triumphs over hostile, wild, and remote landscapes (Terrall, 1998). Feminist science studies began critiquing the gendered dimensions of environmental knowledge several decades ago (Merchant, 1980; Plumwood, 1993; Haraway, 1988). These scholars and others since (e.g. Buck et al., 2014) have argued that the Baconian view of knowledge engendered a strong tendency in the environmental sciences to classify, measure, map, and, ideally, dominate and control nonhuman nature as if it were a knowable and predictable machine, rather than dynamic, chaotic, unpredictable, and coupled natural-human systems.

Such feminist critiques apply today to glaciology, climate sciences, and global environmental change research more broadly. Terry (2009: 6), for example, argues that climate discourse 'is still a stereotypically "masculine" one, of new technologies, large-scale economic instruments, and complex computer modeling', which for glaciers can render them static, essentialized, and passive (also see Moosa and Tuana, 2014).

Fleming (2010) finds a similar story of domination in the climate sciences, in which 20th-century scientists and engineers used cloud seeding and other geoengineering strategies to manipulate weather, steer storms, and make rain. Technoscientific control is a dominant trope in climate change discourse and knowledge, and it is by nature highly gendered (Israel and Sachs, 2013). Much geographical fieldwork involves this masculinist reflexivity generating supposed objectivity through distance from and disinterest in the subject (Coddington, 2015; Sundberg, 2003). These conclusions transcend gendered dimensions of knowledge by acknowledging broader trends in Western sciences that have sought to place science at a god-like vantage from nowhere, ignoring both situated knowledges and the geography of science (Haraway, 1988; Shapin, 1998; Livingstone, 2003).

Gendered aspects of cryospheric knowledge have existed for centuries. In the 1730s, for instance, the French crown sent geodetic expeditions to Peru and the Arctic (Lapland). The naturalist-adventurers chronicled in their reports how they overcame savage environments and bitter cold conditions, frequently celebrating their selfless, heroic risk taking. As the Arctic explorer Pierre-Louis Moreau de Maupertuis explained (characteristically for this genre of scientific writing), 'you may imagine what it is to walk in two feet of snow, carrying heavy measuring sticks, which must be continually set down in the snow and retrieved. All this in a cold so great that when we tried to drink eau-de-vie, the only drink that could be kept liquid, the tongue and lips froze instantly against the cup and could only be torn away bleeding' (quoted in Terrall, 1998: 230). Terrall (1998: 230) concludes that 'the physical strength and perseverance necessary to conquer such obstacles made of the returning men of science not just selfless seekers of truth, but tough adventurers'. But the Lapland and Peru expeditions were also about promoting France's prestige in the wake of new scientific discoveries: male triumph over hostile nature and isolated spaces in the name of science fed nationalism and colonialism, and these forces co-constituted a masculinist glaciology.

When debates about glacier motion emerged in the second half of the 19th century, two central protagonists – the early leading glaciologists James Forbes and John Tyndall – competed for credibility by pinning their scientific contributions to their abilities as 'manly' mountaineers and heroic conquerors of the European Alps. Forbes theorized that glaciers behaved more like a semi-fluid body, flowing downhill as a viscous fluid rather than as a solid object. He highlighted his fieldwork in the mountains and among the glaciers to legitimate his theory. Tyndall, on the other hand, argued that glaciers moved more like a solid substance flowing over bedrock. He eventually triumphed in this debate, contends Hevly (1996), because Tyndall mobilized his greater fame as a mountaineer – having achieved many pioneering first ascents – and deployed a rhetoric of manly risk and exertion. There was what Hevly calls a 'culture of field science' in the 19th century that favored 'authentic, rigorous, manly experience', and scientists – let alone women – who did not explicitly demonstrate that their glaciological conclusions stemmed from heroic, manly adventures struggled to make their scientific claims credible. Glaciology was for muscular gentlemen scientists. Women could read about glaciers in the Alps, but they were not fit for glaciological research, field science,

or even alpine tourism. And men like Forbes who lacked the manly heroism of risk-taking mountaineers lost scientific credibility that hinged on masculinism.

Heroic conquests were also central to Arctic and Antarctic exploration from the 19th century. The Arctic was an important site of American exploration in the 19th century because it was a space where the nation's anxieties about the perils of over-civilization, 'manly character and racial purity' could be tested (Robinson, 2006). Ice had a great hold on the British imagination at the same time, as the Arctic was a space in which British explorers could manifest their evangelical Christianity while simultaneously affirming the place of women in the domestic sphere through passive consumption of heroic and manly stories (Spufford, 1999). Antarctic exploration in the first half of the 20th century continued this emphasis on manly endeavor, especially through military structures, such as through the centrality of the Royal Navy to British expeditions at both poles, or the mid-20th-century American projections into Antarctica (Belanger, 2006; Rose, 1980) and the Arctic (Farish, 2013; Martin-Nielsen, 2012, 2013). These same masculinist tendencies were also reinforced through the scientific and geographical institutions that sponsored research and exploration, such as the Royal Geographical Society in London – which did not admit women fellows until 1913 (Jones, 2003) – or the Scott Polar Research Institute at the University of Cambridge, where work, despite discourses of masculine adventure and field research, relied on the (barely recognized) library and administrative labor of women (Roberts, 2011).

Masculine and heroic rhetoric was so dominant that attempts to reframe discourses of Arctic work in the 1950s and 1960s – as part of broader attempts by environmental scientists to make their science more 'scientific' through experimentation rather than observation – had limited success. The scientific leaders of the Canadian Polar Continental Shelf Project (1958–70), for example, attempted to frame the Arctic as an 'experimental space' rather than an 'expeditionary space', as the basis of the credibility of both their scientific work and Canada's territorial aspirations. Yet, their deployment of 'a precarious authority of experiment' fared poorly in the course of difficult Arctic field work; they could not escape the 'Boy Scout attitude to Arctic fieldwork' and the 'epistemic baggage of the exploratory tradition and adventurous observation'. Though these attempted reframings of Arctic work did not preclude latent masculinities, they did suggest tensions with more explicit masculinities (Powell, 2007).

These masculinist and heroic narratives persist today. The Ohio State University glaciologist Lonnie Thompson, who extracts and studies high-mountain ice cores, for example, has been described as today's 'Indiana Jones' and 'one of the true scientific heroes of our age' (Struck, 2006; Krajick, 2002). While Thompson conscientiously studies ice and works with local communities (Bowen, 2005), media and popular accounts cast him, regardless of his actual intentions, as a pioneer explorer, overcoming hardships and conquering supposedly unknown mountains in distant places. Most popular accounts of Thompson – which often overlook the presence of his wife, Ellen Mosley-Thompson, a world-renowned ice researcher – focus explicitly on his overcoming asthma and a host of other obstacles while conducting fieldwork. Overcoming personal hardship is also at the center of the documentary film *Chasing Ice* (Exposure, 2012), and its protagonist, the filmmaker photographer James Balog. Instead of focusing on the glaciers that Balog photographs, the film follows him and his Extreme Ice Survey into 'treacherous terrain' where Balog struggles with failing knees, strenuous conditions, falling rocks and ice, and existential risk to tell the tale of vanishing glaciers. Balog's assistants even wonder in one scene if they should have stuck to their office job given the risks they face in the field. Balog may not have chosen this approach,

but the filmmakers and media adhere to tropes of masculine vigor, risk, adventurous exploration, and heroic science to attract audiences and validate research, thereby sustaining these masculinist glacier narratives into the 21st century.

Thompson and Balog's work is impressive to be sure because collecting the data they gathered was no easy feat and they are yielding insights for science and climate change impacts. But read alongside older heroic scientific narratives, the masculinist attributions ascribed to this type of field science remain prevalent over three centuries. To be credible, glaciologists, according to most commentators, still need to be experienced mountain climbers to overcome high altitude, limited oxygen, cold temperatures, circumscribed logistical support, and overall rugged working conditions. As Savage (2015: 396) reports in the journal *Nature*, 'Young scientists who are considering a career in ice-core palaeoclimatology ought to have some experience with climbing, says Doug Hardy of the University of Massachusetts Amherst, if only to know whether or not they can handle it.' While Savage recognizes that those without 'the inclination or the ability to climb glaciers' can find other positions in glaciology, such as computer modeling, the article's sub-headline ('Climb any mountain: Glaciology is an outdoors game') certainly does not celebrate these indoor desk jobs. Nor does such a depiction consider class barriers for entry into the field, such as the high costs of acquiring and maintaining necessary alpine skills. Alternative knowledges and practices are marginalized in this sustained masculinist atmosphere, restricting scientific questions asked, practitioners involved, methods employed, sites studied, and results achieved.

Manliness in the field thus makes the science (and scientist) more credible. A recent feature in the *New York Times* follows researchers onto the Greenland ice sheet, for example, where they race against time and a precarious helicopter, survive the 'frozen landscape' of this hostile environment, and altruistically overcome death to get glacier runoff data. As Lincoln Pitcher was quoted as saying, if his fellow researcher fell into the river atop the ice sheet, 'the death rate is 100 percent' (Davenport et al., 2015). The article focuses very little on the scientific questions asked, or even the scientific implications of the study beyond broad claims about glacier shrinkage and sea level rise. It focuses instead on the *processes* of doing glaciological science, not the science itself. Yet *New York Times* coverage for these researchers – especially the graduate student at the center of it – can significantly enhance a career. In this way, the portrayal of masculinist researchers in the media (because that is what sells, presumably) can shape scientific credibility in the academy, such as with hiring and possibly even with peer reviewing. Being a pioneer, being first, enduring physical hardship, risking death, overcoming wild nature – in short, being as manly as the Victorian mountaineer-glaciologists were more than a century ago – continues to influence scientists' credibility, or on the other side, their lack of credibility for those who cannot pitch their research through such masculinist frameworks.

V Systems of scientific domination

Feminist glaciology builds on feminist postcolonial science studies and feminist political ecology to understand how gender, power, and inequality are embedded in systems of scientific domination (Schiebinger, 2014). Such power structures maintain glaciology as a discipline concentrated in the wealthy developed world, often termed the Global North, with generally weak institutional representation from the developing world or indigenous communities. This pattern exists for global climate simulations in general, which are conducted by European and North American scientists with little to no representation from Central and South America, Africa, the Middle East, or

South Asia (Edwards, 2011). The feminist lens is crucial for effective analysis of what might look on the surface like postcolonial or hegemonic structures of development. But global power imbalances and gender inequality co-constitute each other – and the natural sciences and glaciology in particular. Current climate change discussions, for example, perpetuate power discrepancies through what Israel and Sachs (2013: 34–5) refer to as 'the centrality of mathematical and technological science . . . structured by masculinist ideologies of domination and mastery', thus determining who can or cannot participate in climate science and policy-making. Such institutional, cultural, and scientific practices also affect glaciological knowledge. While there are, on paper, few recognized glaciologists from the Global South (for exceptions see Carey, 2010), such recognition is predicated upon a specific type of knowledge production that is restricted to a group of scientists who often cannot be divorced from larger processes of colonialism, imperialism, patriarchy, and capitalist resource extraction.

Questions of who produces glaciological knowledge, and how such knowledge is used or shared, take on real implications when considered through feminist postcolonial science studies and feminist political ecology lenses. Specifically, the feminist approach opens up marginalized knowledge and exposes how larger structures of domination have worked historically to suppress certain voices. It reveals how people across the planet have been living with glaciers for centuries and have produced wide ranges of glaciological knowledge – folk glaciology – that is rarely recognized within the scientific discipline of modern glaciology. We use the term 'folk glaciology' to refer to significant glacier-oriented knowledges produced at different times and places by diverse peoples, cultures, and social groups.

For instance, in Canada's Yukon Territory, glacier knowledge of elder indigenous women has both a gendered context and offers alternative visions of ice compared to Western sciences. Cruikshank (2005) explains for Northwest North America that knowledge of the landscape is influenced profoundly by culture, gender, age, and the personal experiences of each individual living with glaciers. Additionally, whereas glaciologists may try to measure glaciers and understand ice physics by studying the glacial ice itself, indigenous accounts do not portray the ice as passive, to be measured and mastered in a stereotypically masculinist sense. 'The glaciers these women speak of', explains Cruikshank (2005: 51–3), 'engage all the senses. [The glaciers] are willful, capricious, easily excited by human intemperance, but equally placated by quick-witted human responses. Proper behavior is deferential. I was warned, for instance, about firm taboos against ''cooking with grease'' near glaciers that are offended by such smells. . . . Cooked food, especially fat, might grow into a glacier overnight if improperly handled.' The narratives Cruikshank collected show how humans and nature are intimately linked, and subsequently demonstrate the capacity of folk glaciologies to diversify the field of glaciology and subvert the hegemony of natural sciences.

Such knowledge diversification, however, can meet resistance, as folk glaciologies challenge existing power dynamics and cultures of control within glaciology. For instance, in response to Cruikshank's detailed and highly acclaimed research, geographer Cole Harris suggested instead that Cruikshank attributed too much weight to 'Native' stories and non-scientific understandings of glaciers. He questioned the relevance of indigenous narratives about sentient glaciers in today's modern world by explaining how he consulted a colleague, 'an expert on snow', about why glaciers advanced rapidly (surged). The expert 'spoke of ground water, friction, and the laws of physics. Is it possible, I [Harris] asked, that they surge because they don't like the smell of grease? He looked at me blankly, slowly shook his head, and

retreated into his office' (Harris, 2005: 105). Harris is asking what place indigenous knowledge and storytelling have in the world. Although his other work has examined indigenous understandings and uses of local space, nature, and resources (e.g. Harris, 2002), in the case of his Cruikshank critique Harris seemed uncomfortable accepting that knowledge is situated in particular places and contexts (Haraway, 1988; Livingstone, 2003), that values and morals related to ice vary across cultures (e.g. Gearheard et al., 2013; Krupnik et al., 2010), and that, as Cruikshank illustrates quite clearly, glaciological mapping and other scientific research existed within and facilitated systems of colonial expansion, capitalist resource extraction, and the subjugation of indigenous peoples in the region (Cruikshank, 2005, 2012a, 2012b). It must be emphasized that Cruikshank does not advocate a simple inclusion of local or indigenous knowledge into Western knowledge or global technocratic or bureaucratic practice, arguing that this systematizing 'can set in motion processes that fracture and fragment human experience' (Cruikshank, 2004, p. 18). Conscious of this position, the feminist glaciology framework asks that researchers accept a plurality of knowledges and recognize embedded systems of domination. The goal is neither to force glaciologists to believe that glaciers listen nor to make indigenous peoples put their full faith in scientists' mathematical equations and computer-generated models (devoid of meaning, spirituality, and reciprocal human-nature relationships). Rather, the goal is to understand that environmental knowledge is always based in systems of power discrepancies and unequal social relations, and overcoming these disparities requires accepting that multiple knowledges exist and are valid within their own contexts.

While folk glaciologies were often marginalized through Western colonialism, the discipline of glaciology experienced growth and support as a result of European and US imperialism and geopolitical expansion – already highly gendered projects in themselves (Cohn, 1987; Levine, 2007; Woollacott, 2006) – in turn helping to materially and discursively undergird those projects. The United States, for example, had an overwhelmingly militarized relationship with the polar regions in the early Cold War period, from which glaciology benefitted immensely, gaining institutional resources, growth, standing, and credibility. The US Antarctic operations Highjump and Windmill in the late 1940s were intended to prepare the military for conflicts in cold regions, in the process constituting, for US scientists especially, a regionally-expansive and technologically-driven domination of the south polar region (Belanger, 2006; Rose, 1980).

The US had a similarly militarized relationship with the Arctic (Farish, 2013; Martin-Nielsen, 2012, 2013). In 1949, US Air Force Lt. Col. Emil Beaudry convinced his superiors that, as Greenland was likely to be the 'avenue of approach for untold destruction, [and] unless guarded could well spell doom for the United States as a nation', whichever country was able to 'completely master [Greenland] would possess a new weapon that could not be countered or molested' (quoted in Martin-Nielsen, 2012: 69–71). Mastering and defending Greenland, however, required mastering its ice sheet, and new glaciological knowledge was only possible with the resources available to the US military. In 1949 Henri Bader, the chief scientist for the US government's Snow, Ice and Permafrost Research Establishment (SIPRE), complained that, while there was general knowledge of the location and easily-discernible characteristics of glaciers, more complex and sophisticated knowledge of their physical processes was poor (Bader, 1949: 1309). The substantial growth of glaciology in subsequent decades relied, to an important degree, on these military demands. This militarization of the polar regions and the intellectual and institutional growth of glaciology were part of broader US geopolitical visions

and strategies during the Cold War, which were pursued by a particular group of men as policymakers who were products of specific elite masculinities (Dean, 2003), operating in the context of anxieties about American masculinities (Cuordileone, 2005), and with particular discourses of masculinity and male bodies, especially in distant places like the Arctic (Farish, 2010).

Structures of power and domination also stimulated the first large-scale ice core drilling projects – these archetypal masculinist projects to literally penetrate glaciers and extract for measurement and exploitation the ice in Greenland and Antarctica. These ice cores, which have revealed glacial-interglacial cycles and validated trajectories of both climate change and anthropogenic warming, also began as part of American and Soviet Cold War geostrategic projections into the polar regions. The first ice core from Camp Century in Greenland emerged from a drilling program begun in 1959, even before Willi Dansgaard introduced a method of isotope analysis for paleoclimates. Ice coring, in other words, began with a military purpose but eventually found a scientific function (Martin-Nielsen, 2013). The even longer ice cores from Vostok in the center of the East Antarctic ice sheet began with similar geostrategic motives: the Soviet Union was trying to exert its control of Antarctica by establishing the Vostok Station at the 'pole of relative inaccessibility' – the furthest point from the sea in Antarctica. Ice core drilling at Vostok began in the late 1950s, and by the 1980s the core offered a longer climatic record than the first Camp Century core and clearly demonstrated the links between carbon dioxide levels and past temperatures (Ueda and Talalay, 2007; Turchetti et al., 2008). These ice cores were born in the contest for scientific authority and geostrategic control of the polar regions, manifesting the centrality of power, conquest, and national security in the history of glaciological knowledge.

The military and geopolitical dimensions of glaciers persist today, albeit in different forms that illustrate the importance of feminist glaciology extending 'beyond gender' to other aspects of inequality, power-knowledge dynamics, and imperialism. In official US discourse, retreating glaciers are framed as threats to national security and international stability, and therefore knowledge of ice is essential to maintaining geopolitical power. Retreating glaciers rank with drought, flooding, sea level rise, and epidemics as critical threats to US national security. Former CIA director R. James Woolsey explained when he testified before the US House of Representatives in February 2009 that:

> One of the fastest set [sic] of melting glaciers is apparently in the Andes, and if we think we have trouble coming up with a sound and agreed-upon immigration policy for the United States now, what is it going to be like if our southern borders are seeing millions of our hungry and thirsty southern neighbors headed toward temperate climates?

For Woolsey, US national security hinges on increased knowledge of glaciers, much as it was integral to Canadian and US expansion into the Yukon and Alaska in the 19th century, as well as to Soviet and US strategists in the early Cold War years. Systems of domination and structures of power and patriarchy have long fed the production of glaciological knowledge.

VI Alternative representations

If the intersecting forces of colonialism, neoliberalism, and patriarchy have historically silenced and marginalized certain ways of knowing and types of knowledge produced by particular groups, such as women or indigenous people, then feminist glaciology – drawing from feminist political ecology and feminist postcolonial science studies – seeks to expose those more-than-science voices and offer a diversity of representations of cryoscapes. Researchers across a range of disciplines have increasingly advocated for greater plurality in knowledge

about and representations of global environmental change. Castree et al. (2014: 765), for example, contend that

> other forms of knowledge, discourse and understanding [beyond natural sciences] must be properly acknowledged, precisely because they both affect, and are affected by, science and technology. These forms range beyond the cognitive to encompass the moral, spiritual, aesthetic and affective.

These calls align with those of feminist political ecology and feminist postcolonial science studies that seek to unsettle dominant Western assumptions, narratives, and representations which tend to privilege the natural sciences and often emerge through the co-constituted processes of colonialism, patriarchy, and unequal power relations (Harding, 2009). Dominant narratives can erase local, regional, and even national variation and the diversity of perspectives, including those of women and other marginalized peoples (Israel and Sachs, 2013). Feminist political ecologists have thus sought to use innovative research methods such as storytelling, narrative, literature, and the visual arts to go 'beyond gender' to find new voices discussing and representing global environmental change (Harris, 2015; Mollett and Faria, 2013; Coddington, 2015: 215). Feminist glaciology promotes alternative glacier representations (which include folk glaciologies) and calls for transdisciplinary knowledge integration and methodology, which is crucial for putting glacier knowledges into their human contexts (Hewitt, 2014a).

In contrast to trends in masculinist glaciology, one example of alternative glacier representations includes glacier-oriented visual and literary arts, which are particularly illustrative of how ice may be meaningful and significant beyond common efforts of control and domination. Visual and literary arts re-position and re-envision glaciers as greater than their usual status as passive research subjects and into various cultural fields comprised of social myths, images, characters, performances, and artworks. Artists including Resa Blatman, Zaria Forman, Camille Seaman, Spencer Tunick, Claudia Märzendorfer, and Joan Perlman articulate new narratives of human-glacier relationships by approaching ice through feeling and affect, emotional response, sense of place, the personal and the intimate, kinship and family rather than through the attributes and characteristics of the dominant, masculinist scientific glaciology often characterized by control, prediction, ice penetration, measurement, and quantification. Many of the examples below from the visual and literary arts veer away from the more typical, masculinist representations of glaciers by offering alternative gendered ice depictions.

For instance, Scottish visual artist Katie Paterson's 2007 work, *Langjökull, Snæfellsjökull, Solheimajökull*, depicts the impermanence of glaciers while broadening the notion of glaciers as repositories for climatic records and diverting what it means to 'record' and be a 'record' (Paterson, 2007). Paterson chronicled the ordinary sounds of the Langjökull, Snæfellsjökull, and Solheimajökull glaciers in Iceland, and then transferred the audio tracks to LP micro-groove vinyl 'ice' records – records created by casting and freezing the glaciers' own meltwater. She then played the frozen records simultaneously on three turntables as they melted. The audio recordings (available at http://www.katiepaterson.org/icerecords/) fuse glacier sounds with the high whine of the ice record itself. After ten minutes, the actual ice LP record deteriorates and the sound melts away. Climatic data from ice core records are often imported into climate models, while rates of glacier retreat chronicling meters melted per year are usually taken directly at face value, with policy implications. Both the ice cores and ice loss measurements feed homogenizing global narratives of glaciers with somewhat restricted views of the cryosphere, lacking emotional and sensory interactions with the ice that occurs in Paterson's artworks. Paterson and

other artists thus intervene in such 'truths' by presenting purposefully imprecise social and scientific methodologies and works. Paterson's artwork builds on an earlier project where she submerged a phone line connected to Vatnajökull, Iceland and Europe's largest glacier. People could call the glacier (+44(0)7757001122) and listen to the distinctive pops, trills, and gurgles of the ice. More than ten thousand people called during the installation. Such a project demonstrates how the social constructions of space, time, and knowledge can be manipulated in significant ways and can engage human senses. Paterson's work challenges the conceits of scientific distance and impartiality: glaciers are no longer remote but just a phone call away. These interactions and acquaintances with the ice diverge from the more masculinist domination of the glaciers in polar colonial science, ice core extraction, and quantification.

Other artists offer alternative glacier representations by melding science and art. In *Columbia Glacier 4, 1990 USGS 2011*, landscape painter Diane Burko depicts a realistic image of a white-yellow thickly painted glacier pouring into a dark foreground. The prominent red stylized time stamp in the lower right corner is evocative of common scientific images of glaciers. Juxtaposing a clearly 'painted' glacier, Burko blurs the lines of authority and science, pushing viewers to consider how glacier narratives are produced, circulated, and given credibility and authority across time and space, and by whom. Her paintings, which utilize up-to-date scientific data such as individual glacier recession rates, inhabit a socially problematic more-than-science position of being simultaneously 'representationally accurate' but also 'representationally artistic'. They thus challenge dominant structures of authority and hegemonic knowledge construction because in more formal scientific glaciology these positions are often treated as mutually exclusive. Burko also paints glaciers from an aerial, top-down perspective, one that appropriates a gaze generally associated with scientific credibility and accuracy. Such a gaze has been troubled by feminist researchers who argue that the 'conquering gaze' makes an implicit claim on who has the power to see and not be seen (see e.g. Gaard, 1993; Harding, 1987; Merchant, 1987). Burko's aerial paintings additionally interact with common representations of glaciers through images constructed with GIS and satellite technologies. Garb (1994) applies a feminist science studies lens to consider this 'distant-view' as masculine, reminiscent of detached, voyeuristic, 'pornographic' images. Burko's glacier paintings challenge assumptions about expertise (who has access to and knowledge of such technologies that determine widely-circulated glacier representations), about local knowledge (much messier and complicated than satellite imagery), and about universalism (where earth systems and satellite representations obscure on-the-ground details and contexts). More broadly, however, Burko's work contests the perceived gulf between art and science itself: glacier artwork does teach about glaciology, even if it is not satellite imagery from 'true' satellites.

In addition to glacier artwork, there is also a growing body of literature that expands understandings of the cryosphere and grapples with core issues in feminist geography. Uzma Aslam Khan's (2010) short story 'Ice, Mating', for example, explores religious, nationalistic, and colonial themes in Pakistan, while also featuring intense sexual symbolism of glaciers acting upon a landscape. Khan writes: 'It was Farhana who told me that Pakistan has more glaciers than anywhere outside the poles. And I've *seen* them! I've even seen them *fuck!*' (Khan, 2010: 102, emphasis in original). This fictional story draws from local understandings of Karakoram geomorphology, their cultures of glaciers and mountains, the gendered nature of landscape perceptions, and the legacies of colonialism. In Khan's story, glacier knowledge, while highly sexualized, is acquired through locals' interactions with the surrounding glaciers

rather than through classic Western channels of knowledge dissemination through reports and academic articles. Khan subverts traditional roles of who acts upon whom, complicating patriarchal assumptions that, as with society, nature must have rulers and the ruled (Keller, 1983). Khan also points to the long tradition of local women interacting with glaciers and early Western-funded glaciological expeditions in the Karakoram (Hewitt, 2014b). By explicitly highlighting women's roles in producing glaciological knowledge, the story simultaneously avoids and points out the common practice of 'erasure' in which the full range of participants in the production of scientific knowledge (in this case, women in glaciology) is ignored or overlooked (Brooks and Hébert, 2006).

The American science fiction and fantasy author Ursula K. LeGuin has also explored ice and glaciers in several works. Her novel *The Left Hand of Darkness* (LeGuin, 1969) upends notions of gender while re-imagining masculine polar exploration. The novel sends two fugitives on an 81-day journey across the Gobrin Glacier on the fictional planet of Winter. In a frozen world without warfare, LeGuin imagines a place without men and women, where there are no fixed or different sexes. In her 1982 short story *Sur*, LeGuin portrays a group of South American women who reach the South Pole two years *before* the all-male Amundsen and Scott parties. But these women leave no record of their activities in Antarctica, and upon their return tell nobody of their feat. Such a radical, postcolonial, feminist narrative about polar exploration serves to underscore the history still perpetuated today, a history imbued with masculinity and heroic men (Bloom, 2008).

Other literature tackles emotional, psychological, and sexual interactions with glaciers. Alexis Smith's (2012) debut novel *Glacier* features a main character who acts both as a metaphor and a voice for the shrinking glaciers that she dreams about vividly, and depicts individuals' and communities' psychological experiences and challenged identities through glacier loss. In Sheryl St. Germain's (2001) 'To Drink a Glacier', the author interprets her experiences with Alaska's Mendenhall Glacier as sexual and intimate. When she drinks the glacier's water, she reflects:

> That drink is like a kiss, a kiss that takes in the entire body of the other ... like some wondrous omnipotent liquid tongue, touching our own tongues all over, the roofs and sides of our mouths, then moving in us and through to where it knows ... I swallow, trying to make the spiritual, sexual sweetness of it last. (St. Germain, 2001: 201)

The story portrays the glacier's sensual, embodied nature as the main character goes through her own midlife sexual awakening.

St. Germain, LeGuin, Khan, and many others – from Roni Horn (2009) to Pauline Couture (2005) – approach glaciers from distant and varied disciplinary and artistic spaces compared with glaciologists or even anthropologists studying human-glacier interactions. Such alternative representations of glaciers are rarely incorporated or even acknowledged within greater discourses of glaciology and global environmental change research. Yet their voices should not simply be disregarded, overshadowed by Western science, or, worse, relegated from policy contexts where, in fact, the human experience with ice matters greatly. These alternative representations from the visual and literary arts do more than simply offer cross-disciplinary perspectives on the cryosphere. Instead, they reveal entirely different approaches, interactions, relationships, perceptions, values, emotions, knowledges, and ways of knowing and interacting with dynamic environments. They decenter the natural sciences, disrupt masculinity, deconstruct embedded power structures, depart from homogenous and masculinist narratives about glaciers, and empower and incorporate different ways of seeing, interacting, and representing glaciers – all key goals of feminist glaciology.

VII Conclusions

Ice is not just ice. The dominant way Western societies understand it through the science of glaciology is not a neutral representation of nature. The feminist glaciology framework draws attention to those who dominate and frame the production of glaciological knowledge, the gendered discourses of science and knowledge, and the ways in which colonial, military, and geopolitical domination co-constitute glaciological knowledge. Even in a globalized age where the place of women and indigenous people has improved markedly in some parts of the world, masculinist discourses continue to dominate, in subtle and determinative ways. Feminist glaciology advocates for a shift of preoccupations in research, policy, and public perceptions from the physical and seemingly natural, to a broader consideration of 'cryoscapes', the human, and the insights and potentials of alternative ice narratives and folk glaciologies.

The critique and framework outlined here illuminate experiences and narratives that emerged historically but remain potent today. Public discourse on the cryosphere continues to privilege, quite explicitly, manly endeavours and adventures in the field, and those who conduct their science in the manner of masculinist glaciologists and other field scientists of decades and centuries past. A new documentary by French filmmaker Luc Jacquet (2015) about the preeminent French glaciologist and geochemist Claude Lorius perpetuates narratives of heroic domination of nature, while, in interesting ways, noting that 'triumphant man' is responsible for the global problems that make Lorius' research so necessary. At the same time, in the midst of extensive coverage of the polar regions in the context of climate change, the *New York Times* has published articles that foreground the dangerous field in Greenland, thereby validating manly, heroic fieldwork while simultaneously relegating work with models and computers to something like 'armchair glaciology' (Davenport et al., 2015; Gertner, 2015). Unlike past narratives, there are subtleties and tensions within these public discourses, especially as they often seek to see scientific work in more detail, a detail that can soften or undercut the individual exertions on display. However, they still privilege stereotypical and masculinist practices of glaciology. Other narratives, however, challenge these practices, thereby generating alternative approaches to ice. Emerging from Australia, the Homeward Bound initiative plans a 'state of the art leadership and strategic program for 78 women in science from around the globe' to travel to Antarctica in late 2016, one of its aims being to 'explore how women at the leadership table might give us a more sustainable future' (Homeward Bound, 2015).

The call for a feminist glaciology is not limited to ice and glaciers, but is a larger intervention into global environmental change (and especially climate change) research and policy. As international negotiations remain stalled and governmental commitments to change and reform are fitful and seemingly ineffectual, those studying environmental change and aware of its significant effects and dangerous potentials continue to search for ways of stemming the tides of change as well as forming just and equitable global structures for addressing it. The feminist glaciology framework articulates with these larger quests in at least two ways. First, it repeats the demands for increased presence of humanities and social science perspectives in global environmental change research, policy, and broader public discourse. Many humanities and social science disciplines and sub-disciplines have given significant attention to these issues, but there remain boundaries between these analyses and those considered central to the environmental change question. The natural sciences that drive and undergird environmental change policy are often asked by decision-makers and the media to speak for society or frame research and policy questions

for humanity. But the natural sciences are not equipped to understand the complexities and potentialities of human societies, or to recognize the ways in which science and knowledge have historically been linked to imperial and hegemonic capitalist agendas. Feminist glaciology participates in this broader movement by suggesting richer conceptions of human-environment relations, and highlighting the disempowering and forestalling qualities of an unexamined and totalizing science.

Second, we reiterate the need not only to appreciate the differential impacts of environmental change on different groups of people – men and women, rich and poor, North and South – but to understand how the science that guides attempted solutions may in fact perpetuate differences because they are, essentially, built on and draw their epistemic power from differentiation and marginalization. Struggles over authority and legitimacy play out in many obvious ways in climate change negotiations. Struggles also happen in less obvious ways, such as in the environmental change research underpinning climate politics. Analysts and practitioners must recognize the ways in which more-than-scientific, non-Western, non-masculinist modes of knowledge, thinking, and action are marginalized. The response to simplistic 'ice is just ice' discourse is not merely to foreground or single out women and their experiences – that would simply perpetuate binaries and boundaries and ignore deeper foundations. Rather, it is a larger integration of human approaches and sensibilities with the existing dominant physical sciences. Global environmental change research must pluralize its ontologies, epistemologies, and sensibilities. Though there is ever-increasing evidence to guarantee future temperature increases, what remains uncertain are the human structures and ideas mobilized to cope with environmental changes as well as to forestall potentially worse outcomes. If we constitute glaciological and global environmental change research differently, we can constitute our future, our gender relations, and our international political economic relations more justly and equitably.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work is based upon work supported by the US National Science Foundation under grant #1253779. Thanks to the Geography Colloquium Series at Ohio State University for valuable input on this project.

References

Allison EA (2015) The spiritual significance of glaciers in an age of climate change. *WIREs Climate Change* 6: 493–508.

Arora-Jonsson S (2011) Virtue and vulnerability: Discourses on women, gender and climate change. *Global Environmental Change* 21: 744–751.

Aukland K (2014) Do you have to be a tough man to be a polar researcher? *Committee for Gender Balance and Diversity in Research Website*. Available at: http://eng.kifinfo.no/nyhet/vis.html?tid=88216 (accessed 20 February 2015).

Bader H (1949) Trends in glaciology in Europe. *Geological Society of America Bulletin* 60: 1309–1314.

Belanger DO (2006) *Deep Freeze: The United States, the International Geophysical Year, and the Origins of Antarctica's Age of Science*. Boulder, CO: University Press of Colorado.

Bloom L (1993) *Gender on Ice: American Ideologies of Polar Expeditions*. Minneapolis, MN: University of Minnesota Press.

Bloom L (2008) Polar fantasies and aesthetics in the work of Isaac Julien and Connie Samaras. *The Scholar and Feminist Online* 7. Available at: http://sfonline.barnard.edu/ice/print_bloom.htm (accessed 4 September 2014).

Bloom L, Glasberg E and Kay L (2008) Introduction: Gender on ice. *The Scholar and Feminist Online* 7. Available at: www.barnard.edu/sfonline (accessed 13 September 2014).

Blum A (1980) *Annapurna: A Woman's Place*. San Francisco, CA: Sierra Club Books.

Bolen A (2006) Glaciologist puts her girls on ice. *Smithsonian*. Available at: http://www.smithsonian.com/science-nature/glaciologist-puts-her-girls-on-ice-133472775/ (accessed 13 September 2014).

Bolin I (2009) The glaciers of the Andes are melting: Indigenous and anthropological knowledge merge in restoring water resources. In: Crate SA and Nuttall M (eds) *Anthropology and Climate Change: From Encounters to Actions*. Walnut Creek, CA: Left Coast Press, 228–239.

Bowen M (2005) *Thin Ice: Unlocking the Secrets of Climate Change in the World's Highest Mountains*. New York: Henry Holt.

Brooks DE and Hébert LP (2006) Gender, race, and media representation. *Handbook of Gender and Communication* 16: 297–317.

Brown RA (2002) *Women on High: Pioneers of Mountaineering*. Boston, MA: Appalachian Mountain Club Books.

Buck HJ, Gammon AR and Preston CJ (2014) Gender and geoengineering. *Hypatia* 29: 651–669.

Burns R (2000) Investigating women's Antarctic experiences: Some methodological reflections on a qualitative, feminist project. *Resources for Feminist Research* 28: 133–149.

Byers E and Sainju M (1994) Mountain ecosystems and women: Opportunities for sustainable development and conservation. *Mountain Research and Development* 14: 213–228.

Carey M (2007) The history of ice: How glaciers became an endangered species. *Environmental History* 12: 497–527.

Carey M (2010) *In the Shadow of Melting Glaciers: Climate Change and Andean Society*. New York: Oxford University Press.

Carey M, Huggel C, Clague JJ and Kaab A (2015) Synthesis and conclusions: The future of high-mountain cryospheric research. In: Huggel C, Carey M, Clague JJ and Kaab A (eds) *The High-Mountain Cryosphere: Environmental Changes and Human Risks*. Cambridge: Cambridge University Press, 339–353.

Castree N, Adams WM, Barry J, Brockington D, Büscher B, Corbera E, Demeritt D, Duffy R, Felt U, Neves K, Newell P, Pellizzoni L, Rigby K, Robbins P, Robin L, Rose DB, Ross A, Schlosberg D, Sörlin S, West P, Whitehead M and Wynne B (2014) Changing the intellectual climate. *Nature Climate Change* 4: 763–768.

Chartier D (2008) The gender of ice and snow. *Journal of Northern Studies* 2: 29–49.

Chipman E (1986) *Women on the Ice: A History of Women in the Far South*. Melbourne: Melbourne University Press.

Chisholm D (2008) Climbing like a girl: An exemplary adventure in feminist phenomenology. *Hypatia* 23: 9–40.

Christmann S and Aw-Hassan AA (2015) A participatory method to enhance the collective ability to adapt to rapid glacier loss: The case of mountain communities in Tajikistan. *Climatic Change*. DOI: 10.1007/s10584-10015-11468-10581.

Clancy KBH, Nelson RG, Rutherford JN and Hinde K (2014) Survey of academic field experiences (SAFE): Trainees report harassment and assault. *PLoS ONE* 9: e102172.

Clarke R and Anteric M (2011) Fanny Copeland and the geographical imagination. *Scottish Geographical Journal* 127: 163–192.

Cochrane R (2014) Climate change, *buen vivir*, and the dialectic of enlightenment: Toward a feminist critical philosophy of climate justice. *Hypatia* 29: 576–598.

Coddington K (2015) Feminist geographies 'beyond' gender: De-coupling feminist research and the gendered subject. *Geography Compass* 9: 214–224.

Cohn C (1987) Sex and death in the rational world of defense intellectuals. *Signs* 12: 687–718.

Conway D, Barnett J, Betsill MM, Lebell L and Seto KC (2014) Global environmental change: Taking stock at a time of transition. *Global Environmental Change* 25: 1–4.

Couture P (2005) *Ice: Beauty, Danger, History*. Toronto: McArthur.

Cruikshank J (2004) Uses and abuses of 'traditional knowledge': Perspectives from the Yukon Territory. In: Anderson DG and Nuttall M (eds) *Cultivating Arctic Landscapes: Knowing and Managing Animals in the Circumpolar North*. New York: Berghahn Books, 17–32.

Cruikshank J (2005) *Do Glaciers Listen? Local Knowledge, Colonial Encounters, and Social Imagination*. Vancouver: University of British Columbia Press.

Cruikshank J (2012a) Are glaciers 'good to think with'? Recognising indigenous environmental knowledge. *Anthropological Forum* 22: 239–250.

Cruikshank J (2012b) Encountering glaciers: Two centuries of stories from the Saint Elias Mountains, Northwestern North America. In: Árnason A, Ellison N, Vergunst J and Whitehouse A (eds) *Landscapes Beyond Land: Routes, Aesthetics, Narratives*. New York: Berghahn Books, 49–66.

Cuordileone KA (2005) *Manhood and American Political Culture in the Cold War*. New York: Routledge.

Davenport C, Haner J, Buchanan L and Watkins D (2015) Greenland is melting away. *New York Times*. Available at: http://www.nytimes.com/interactive/2015/2010/2027/world/greenland-is-melting-away.html?_r=2013 (accessed 22 November 2015).

Dean RD (2003) *Imperial Brotherhood: Gender and the Making of Cold War Foreign Policy*. Amherst, MA: University of Massachusetts Press.

Domosh M (1991) Toward a feminist historiography of geography. *Transactions of the Institute of British Geographers* 16: 95–104.

Drew G (2012) A retreating goddess? Conflicting perceptions of ecological change near the Gangotri-Gaumukh Glacier. *Journal for the Study of Religion, Nature and Culture* 6: 344–362.

Dunbar KW and Medina Marcos KD (2012) Singing for shaved ice: Glacial loss and *Raspadilla* in the Peruvian Andes. In: Sinclair J and Pertierra AC (eds) *Consumer Culture in Latin America*. New York: Palgrave Macmillan, 195–205.

Edwards PN (2011) History of climate modeling. *Wiley Interdisciplinary Reviews: Climate Change* 2: 128–139.

Ellis R (2001) *Vertical Margins: Mountaineering and the Landscapes of Neoimperialism*. Madison, WI: University of Wisconsin Press.

Elmhirst R (2011) Introducing new feminist political ecologies. *Geoforum* 42: 129–132.

Elzinga A (2009) Through the lens of the polar years: Changing characteristics of polar research in historical perspective. *Polar Record* 45: 313–336.

Farish M (2010) *The Contours of America's Cold War*. Minneapolis, MN: University of Minnesota Press.

Farish M (2013) The lab and the land: Overcoming the Arctic in Cold War Alaska. *Isis* 104: 1–29.

Finnegan DA (2004) The work of ice: Glacial theory and scientific culture in early Victorian Edinburgh. *British Journal for the History of Science* 37: 29–52.

Fleming JR (2010) *Fixing the Sky: The Checkered History of Weather and Climate Control*. New York: Columbia University Press.

Fogg GE (1992) *A History of Antarctic Science*. Cambridge: Cambridge University Press.

Frohlick S (1999–2000) The 'hypermasculine' landscape of high-altitude mountaineering. *Michigan Feminist Studies* 14: 83–106.

Gaard G (1993) *Ecofeminism: Women, Animals, Nature*. Philadelphia, PA: Temple University Press.

Gagné K, Rasmussen MB and Orlove B (2014) Glaciers and society: Attributions, perceptions, and valuations. *WIREs Climate Change* 5: 793–808.

Garb SH (1994) Sex for money is sex for money: The illegality of pornographic film as prostitution. *Law & Inequality* 13: 281.

Gearheard SF, Holm LK, Huntington H, Levitt JM and Mahoney AR (eds) (2013) *The Meaning of Ice: People and Sea Ice in Three Arctic Communities*. Hanover, NH: International Polar Institute Press.

Gertner J (2015) The secrets in Greenland's ice sheet. *New York Times*. Available at: http://www.nytimes.com/2015/2011/2015/magazine/the-secrets-in-greenlands-ice-sheets.html?_r=2010 (accessed 22 November 2015).

Godden NJ. (2013) Gender and declining fisheries in Lobitos, Perú: Beyond Pescador and Ama de Casa. In: Alston M and Whittenbury K (eds) *Research, Action and Policy: Addressing the Gendered Impacts of Climate Change*. Dordrecht: Springer, ch. 8.

Gosnell M (2005) *Ice: The Nature, the History, and the Uses of an Astonishing Substance*. New York: Alfred A. Knopf.

Halvorson SJ (2002) Environmental health risks and gender in the Karakoram-Himalaya, Northern Pakistan. *Geographical Review* 92: 257–281.

Hanson A-M and Buechler S (2015) Introduction: Towards a feminist political ecology of women, global change, and vulnerable waterscapes. In: Buechler S and Hanson A-M (eds) *A Political Ecology of Women, Water and Global Environmental Change*. New York: Routledge, 1–16.

Haraway D (1988) Situated knowledges: The science question in feminism and the privilege of partial perspective. *Feminist Studies* 14: 575–599.

Harding SG (1987) *Feminism and Methodology: Social Science Issues*. Bloomington, IN: Indiana University Press.

Harding SG (2009) Postcolonial and feminist philosophies of science and technology: Convergences and dissonances. *Postcolonial Studies* 12: 401–421.

Harris C (2002) *Making Native Space: Colonialism, Resistance, and Reserves in British Columbia*. Vancouver: UBC Press.

Harris C (2005) Do glaciers really listen? *BC Studies: The British Columbian Quarterly* 103–106.

Harris LM (2015) A quarter century of knowledge and change: Pushing feminism, politics, and ecology in new directions with feminist political ecology. In: Buechler S and Hanson A-M (eds) *A Political Ecology of Women, Water and Global Environmental Change*. New York: Routledge, xix–xxiii.

Hevly B (1996) The heroic science of glacier motion. *Osiris* 11: 66–86.

Hewitt K (2014a) Glaciers in human life. In: Hewitt K, *Glaciers of the Karakoram Himalaya*. Dordrecht: Springer, 327–351.

Hewitt K (2014b) Glaciers of the Karakoram Himalaya. *Encyclopedia of Snow, Ice and Glaciers*. Dordrecht: Springer, 429–436.

Hewitt K (2014c) *Glaciers of the Karakoram Himalaya: Glacial Environments, Processes, Hazards and Resources*. Dordrecht: Springer.

Heymann M, Knudsen H, Lolck ML, Nielsen H, Nielsen KH and Ries CJ (2010) Exploring Greenland: Science and technology in Cold War settings. *Scientia Canadensis: Canadian Journal of the History of Science, Technology and Medicine* 33: 11–42.

Homeward Bound (2015) Available at: http://homewardboundprojects.com.au/about/ (accessed 10 December 2015).

Horn R (2009) *Vatnasafn/Library of Water: Stykkishólmur, Iceland*. London: Steidl/Edition 7L.

Hulbe CL, Wang W and Ommanney S (2010) Women in glaciology, a historical perspective. *Journal of Glaciology* 56: 944–964.

Hulme M (2010) Claiming and adjudicating on Mt Kilimanjaro's shrinking glaciers: Guy Callendar, Al Gore and extended peer communities. *Science as Culture* 19: 303–326.

Hulme M. (2011) Meet the humanities. *Nature Climate Change* 1: 177–179.

Israel AL and Sachs C (2013) A climate for feminist intervention: Feminist science studies and climate change. In: Alston M and Whittenbury K (eds) *Research, Action and Policy: Addressing the Gendered Impacts of Climate Change*. New York: Springer, 33–51.

Jackson M (2015) Glaciers and climate change: Narratives of ruined futures. *WIREs Climate Change*. DOI: 10.1002/wcc.1351.

Jacquet L (2015) *Ice and Sky*. Wild-Touch Productions and Association. Available at: http://iceandsky.com/ (accessed 10 December 2015).

Jones M (2003) *The Last Great Quest: Captain Scott's Antarctic Sacrifice*. Oxford: Oxford University Press.

Jordan J (25 June, 1969) Loneliness expected. *Columbus Dispatch*. p. 1.

Keller EF (1983) Gender and science. In: Harding S and Hintikka MB (eds) *Discovering Reality: Feminist Perspectives on Epistemology, Metaphysics, Methodology, and Philosophy of Science*. New York: Springer, 187–205.

Khan UA (2010) Ice, mating. *Granta* 112: 89–111.

Klein JA, Hopping KA, Yeh ET, Nyima Y, Boone RB and Galvin K (2014) Unexpected climate impacts on the Tibetan Plateau: Local and scientific knowledge findings of delayed summer. *Global Environmental Change* 28: 141–152.

Korsmo FI (2010) Glaciology, the Arctic, and the U.S. military, 1945–58. In: Naylor S and Ryan JR (eds) *New Spaces of Exploration: Geographies of Discovery in the Twentieth Century*. London: I.B. Tauris.

Krajick K (2002) Ice man: Lonnie Thompson scales the peaks for science. *Science* 298: 518–522.

Krupnik I, Aporta C, Gearheard S, Laidler GJ and Kielsen Holm L (eds) (2010) *SIKU: Knowing Our Ice: Documenting Inuit Sea-Ice Knowledge and Use*. New York: Springer.

Laine P (14 December, 1970) Antarctica: Men risk death to unlock its awesome secrets. *Free Press Washington*.

LeGuin UK (1969) *The Left Hand of Darkness*. New York: Ace Books.

Levine P (2007) *Gender and Empire*. Oxford: Oxford University Press.

Lewander L (2009) Women and civilisation on ice. In: Hansson H and Norberg C (eds) *Cold Matters: Cultural Perceptions of Snow, Ice and Cold*. Umeå: Umeå University and the Royal Skyttean Society, 89–104.

Livingstone DN (2003) *Putting Science in Its Place: Geographies of Scientific Knowledge*. Chicago, IL: University of Chicago Press.

Logan J (2006) Crampons and cook pots: The democratization and feminization of adventure on Aconcagua. In: Vivanco LA and Gordon RJ (eds) *Tarzan Was an Eco-Tourist – and Other Tales in the Anthropology of Adventure*. New York: Berghahn Books, 161–178.

Macdougall JD (2004) *Frozen Earth: The Once and Future Story of Ice Ages*. Berkeley, CA: University of California Press.

Maddrell A (2009) *Complex Locations: Women's Geographical Work in the UK, 1850–1970*. Chichester: Wiley-Blackwell.

Martin-Nielsen J (2012) The other Cold War: The United States and Greenland's ice sheet environment, 1948–1966. *Journal of Historical Geography* 38: 69–80.

Martin-Nielsen J (2013) 'The deepest and most rewarding hole ever drilled': Ice cores and the Cold War in Greenland. *Annals of Science* 70: 47–70.

Merchant C (1980) *The Death of Nature: Women, Ecology, and the Scientific Revolution*. San Francisco, CA: Harper & Row.

Merchant C (1987) The theoretical structure of ecological revolutions. *Environmental Review* 11(4): 265–274.

Miller L (1984) *On Top of the World: Five Women Explorers in Tibet*. Seattle, WA: The Mountaineers.

Mollett S and Faria C (2013) Messing with gender in feminist political ecology. *Geoforum* 45: 116–125.

Moosa CS and Tuana N (2014) Mapping a research agenda concerning gender and climate change: A review of the literature. *Hypatia* 29: 677–694.

National Research Council (2012) *Lessons and Legacies of the International Polar Years 2007–2008*. Washington, DC: National Academies Press.

Naylor S, Dean K and Siegert M (2008) The IGY and the ice sheet: Surveying Antarctica. *Journal of Historical Geography* 34: 574–595.

Nüsser M and Baghel R (2014) The emergence of the cryoscape: Contested narratives of Himalayan glacier dynamics and climate change. In: Schuler B (ed.) *Environmental and Climate Change in South and Southeast Asia*. Leiden: Koninklijke Brill, 138–156.

Orlove B, Wiegandt E and Luckman B (2008a) *Darkening Peaks: Glacier Retreat, Science, and Society*. Berkeley, CA: University of California Press.

Orlove B, Wiegandt E and Luckman BH (2008b) The place of glaciers in natural and cultural landscapes. In: Orlove B, Wiegandt E and Luckman BH (eds) *Darkening Peaks: Glacial Retreat, Science, and Society*. Berkeley, CA: University of California Press, 3–19.

Owston PG and Lonsdale K (1948) The crystalline structure of ice. *Journal of Glaciology* 1: 118–123.

Paterson K (2007) Langjökull, Snæfellsjökull, Solheimajökull. Multimedia arts installation and audio recording. Available at: http://www.katiepaterson.org/icerecords/ (accessed 10 December 2015).

Peck AS (1911) *A Search for the Apex of America: High Mountain Climbing in Peru and Bolivia*. New York: Dodd Mead.

Pettit EC, Mortenson C, Stiles K, Coryell-Martin M and Long L (2010) Girls on ice: Using immersion to teach fluency in science. *American Geophysical Union, Fall Meeting 2010, Abstract #ED32A-06*. San Francisco, CA, USA. Available at: http://adsabs.harvard.edu/abs/2010AGUFMED32A.06P (accessed 10 December 2015).

Phillips P and Phillips C (2010) The nature of feminist science studies. *Resources for Feminist Research / Documentation sur la recherche féministe (RFR/DRF)* 33: 9–16.

Plumwood V (1993) *Feminism and the Mastery of Nature*. London: Routledge.

Pollack H (2009) *A World without Ice*. New York: Penguin Group.

Powell RC (2007) 'The rigours of an arctic experiment': The precarious authority of field practices in the Canadian High Arctic, 1958–1970. *Environment and Planning A* 39: 1794–1811.

Pyne SJ (1986) *The Ice: A Journey to Antarctica*. Iowa City, IA: University of Iowa Press.

Roberts P (2011) *The European Antarctic: Science and Strategy in Scandinavia and the British Empire*. New York: Palgrave Macmillan.

Robinson MF (2006) *The Coldest Crucible: Arctic Exploration and American Culture*. Chicago, IL: University of Chicago Press.

Rose G (1993) *Feminism and Geography: The Limits of Geographical Knowledge*. Minneapolis, MN: University of Minnesota Press.

Rose LA (1980) *Assault on Eternity: Richard E. Byrd and the Exploration of Antarctica 1946–47*. Annapolis, IN: Naval Institute Press.

Savage N (2015) Glaciology: Climatology on thin ice. *Nature* 520: 395–397.

Schiebinger L (2014) *Women and Gender in Science and Technology*. New York: Routledge.

Schnabel L (2014) The question of subjectivity in three emerging feminist science studies frameworks: Feminist postcolonial science studies, new feminist materialisms, and queer ecologies. *Women's Studies International Forum* 44: 10–16.

Schrepfer SR (2005) *Nature's Altars: Mountains, Gender, and American Environmentalism*. Lawrence, KS: University Press of Kansas.

Shapin S (1998) Placing the view from nowhere: Historical and sociological problems in the location of science. *Transactions of the Institute of British Geographers NS* 23: 5–12.

Smith A (2012) *Glacier*. Portland, OR: Tin House.

Sörlin S (2015) Cryo-history: Narratives of ice and the emerging Arctic humanities. In: Evengård B, Larsen JN and Paasche Ø (eds) *The New Arctic*. New York: Springer, 327–339.

Spufford F (1999) *I May Be Some Time: Ice and the English Imagination*. New York: Picador.

St.Germain S (2001) To drink a glacier: Notes from an Alaskan journal. *Women's Studies Quarterly* 29: 196–205.

Struck D (2006) The 'Indiana Jones' of a shrinking realm. *Washington Post*. Available at: http://www.washingtonpost.com/wp-dyn/content/article/2006/2007/2028/AR2006072801995.html (accessed 20 September 2006).

Sullivan W (2 October, 1969) Women to invade male sanctuary. *Toledo Times*.

Sultana F (2014) Gendering climate change: Geographical insights. *The Professional Geographer* 66: 372–381.

Sundberg J (2003) Masculinist epistemologies and the politics of fieldwork in Latin Americanist geography. *The Professional Geographer* 55: 180–190.

Terrall M (1998) Heroic narratives of quest and discovery. *Configurations* 6: 223–242.

Terry G (2009) No climate justice without gender justice: An overview of the issues. *Gender and Development* 17: 5–18.

Turchetti S, Naylor S, Dean K and Siegert M (2008) On thick ice: Scientific internationalism and Antarctic affairs, 1957–1980. *History and Technology* 24: 351–376.

Ueda HT and Talalay PG (2007) *Fifty Years of Soviet and Russian Drilling Activity in Polar and Non-Polar Ice: A Chronological History*. Hanover, NH: US Army Corps of Engineers Cold Regions Research and Engineering Laboratory.

Wertheim M (2005) Young women get serious in a laboratory of ice. *The New York Times*, 8 March. Available at: http://www.nytimes.com/2005/03/08/science/earth/young-women-get-serious-in-a-laboratory-of-ice.html?_r=0 (accessed 10 December 2015).

Williams C and Golovnev I (2015) Pamiri women and the melting glaciers of Tajikistan. In: Buechler S and Hanson A-MS (eds) *A Political Ecology of Women, Water and Global Environmental Change*. New York: Routledge, ch. 11.

Woollacott A (2006) *Gender and Empire*. Houndmills: Palgrave Macmillan.

Yeh ET, Nyima Y, Hopping KA and Klein JA (2014) Tibetan pastoralists' vulnerability to climate change: A political ecology analysis of snowstorm coping capacity. *Human Ecology* 42: 61–74.

Author biographies

Mark Carey holds appointments at the University of Oregon as associate professor of history in the Robert D. Clark Honors College and associate professor of environmental studies. His research focuses on glacier-society dynamics, climate change, natural disasters, water, mountaineering, and health.

M. Jackson is a PhD candidate in geography at the University of Oregon. Jackson is currently a Fulbright-National Science Foundation Arctic Research Fellow investigating glacier-society relationships in Iceland.

Alessandro Antonello is a postdoctoral research fellow at the University of Oregon's Robert D. Clark Honors College. An environmental historian, his research investigates the history of environmental protection and management, science, geopolitics, and ice in Antarctica and the Southern Ocean.

Jaclyn Rushing graduated from the University of Oregon's Robert D. Clark Honors College with a BA in Environmental Studies and Romance Languages. Currently, she is pursuing a MS in Forestry at Oregon State University. Her research interests include human dimensions of natural resources and outdoor recreation.