FACETS
a multidisciplinary open access science journal

RESEARCH ARTICLE

Diversity in geoscience: Participation, behaviour, and the division of scientific labour at a Canadian geoscience conference

Leonora King[a]*, Lucy MacKenzie[a], Marc Tadaki[a], Sara Cannon[a], Kiely McFarlane[b], David Reid[a], and Michele Koppes[a]

[a]Department of Geography, University of British Columbia, 1984 West Mall, Vancouver, BC V6T 1Z2, Canada; [b]Institute for Resources, Environment and Sustainability, University of British Columbia, AERL Building, 2202 Main Mall, Vancouver, BC V6T 1Z4, Canada

*leonora.king@geog.ubc.ca

Abstract

Effective policies promoting diversity in geoscience require understanding of how the values and practices of the community support the inclusion of different social groups. As sites of knowledge exchange and professional development, academic conferences are important culturing institutions that can alleviate or reproduce barriers to diversity in geoscience. This study examines diversity at a 2017 geoscience conference, the joint Canadian Geophysical Union and Canadian Society of Agricultural and Forest Meteorology annual meeting, through observation of participation, presentation content, and behaviour in conference sessions. Across 256 observed presentations, women constituted 28% of speakers, whereas women of colour made up only 5%. Participation rates differed between disciplinary sections, with the most populous sessions (Hydrology and Earth Surface) having the lowest percentage of women. Examination of presentation content reveals that the methods and scholarly contributions of both women and people of colour differed from the majority, suggesting an intellectual division of labour in geoscience. Examination of audience behaviours between presenters reveals how a "chilly climate" can be experienced by women and other marginalized demographics in conferences. We argue that there is more to be done than simply increasing numbers of women or other minorities in geoscientific spaces, and we suggest pathways to making geoscience a more inclusive and democratic pursuit.

Key words: geoscience, women in STEM, gender, ethnicity in science, equity and diversity, conference

Citation: King L, MacKenzie L, Tadaki M, Cannon S, McFarlane K, Reid D, and Koppes M. 2018. Diversity in geoscience: Participation, behaviour, and the division of scientific labour at a Canadian geoscience conference. FACETS 3: 415–440. doi:10.1139/facets-2017-0111

Handling Editor: Dawn Kellett

Received: September 21, 2017

Accepted: January 5, 2018

Published: April 19, 2018

Published by: Canadian Science Publishing

Introduction

Fostering diversity in science is increasingly on the agendas of governments, corporations, universities, and research institutions the world over (e.g., NSERC 2010; NSF 2011; Holmes et al. 2015a; Urry 2015). The scientific community is progressively recognizing that modern science has historically been the domain of an elite, white male minority residing in the Global North, and ethical and instrumental arguments for increasing diversity in science have become well circulated and promoted (e.g., Carey et al. 2016). As an ethical argument, if science is to produce knowledge for the benefit of all of humanity, then it should be open to all humans irrespective of their race, gender, religion, sexual orientation, or any other aspect of their background (e.g., Chachra 2017). Beyond ethical arguments,

instrumental arguments have emphasized research findings that diverse scientific teams are more productive in both quantity and quality of scientific outputs (Guterl 2014; Holmes 2015b; Nielsen et al. 2017). As humans embedded in societies and cultures, scientists internalize certain social and political biases in the ways they interact, and one way to guard against such bias is to solicit a variety of perspectives on an issue, informed by a variety of experiences and backgrounds (Hawkesworth 2010; Chachra 2017).

Despite a growing consensus that the lack of diversity in science presents an inequity requiring action, decades of research, policies, and projects have shown that diversifying science is not as simple as encouraging women and minorities to earn university degrees in science, technology, engineering, and mathematics (STEM) fields. In the geosciences, for example, although there are significant numbers of women earning geoscience degrees in the US (Holmes et al. 2015a) these numbers are not translating into equivalent female representation in academic faculty (Glass 2015) or professional activities such as journal refereeing (Lerback and Hanson 2017). Similarly, lower than expected representation of women has been observed in editorial boards in mathematics (Topaz and Sen 2016) and as invited conference speakers in ecology and conservation (Schroeder et al. 2013; Sardelis and Drew 2016). Women of colour are even more under-represented across STEM degrees and positions, with representation declining with increasing seniority (Ong et al. 2011; Ballenger et al. 2017). This situation has been described as a "leaky pipeline", in which women and other minorities leak out of the system by opting (or being pushed) out of pursuing vocations in their scientific field (Alper 1993; Holmes et al. 2015b).

A large and growing body of literature has explored what causes these "leaks" or barriers, documenting the lived experiences of women and other minorities in science. Well-known issues such as familial obligation and childbirth have been identified as constraints on women's participation in science, but increasingly research is revealing the subtle and invisible ways in which scientific cultures privilege certain perspectives, bodies, and backgrounds and devalue others (Jarreau 2016; Skibba 2016; Cheryan et al. 2017; Nelson 2017; Rosen 2017). Studies have shown, for example, that even with identical resumes men are more positively evaluated as scientists relative to women by job search committees (Moss-Racusin et al. 2012), that women with equivalent mathematical abilities to men nonetheless feel less confident in their own abilities (Ellis et al. 2016), that women are less likely to receive strong reference letters from supervisors (Dutt et al. 2016), and that common representations of science to children prominently portray men as scientists whilst women occupy other roles (Kerkhoven et al. 2016). In geoscience, researchers have explored how fieldwork has been framed by heroic narratives emphasizing danger, strength, and masculine prowess, which has the effect of making women and others feel lacking or not welcome (Bracken and Mawdsley 2004; Carey et al. 2016). Where some social behaviours work indirectly to privilege male researchers relative to their female counterparts, others such as workplace acts of sexual assault, harassment, or sexualization work directly to make women—and particularly women of colour—feel unsafe and unwelcome (Williams et al. 2014; Clancy et al. 2017). Individually, each of these biases may not be enough to push women and people of colour out of science; however, in sum they produce a cumulative climate where certain types of people feel valued and central to the enterprise of science, whereas others do not (Holmes 2015b).

Academic conferences are an important institution in science, facilitating both the sharing of knowledge and the building of professional networks. Scientific conferences are also places where the identities of scientists are constructed; at conferences we learn what is valuable in science, who counts as a legitimate scientist, and what constitutes professional behaviour (Egri 1992; Henderson 2015). For this reason, scholars have been turning their attention towards how academic conferences might remedy (or reproduce) barriers to diversity in the earth and environmental sciences (Schroeder et al. 2013; Sardelis and Drew 2016; Farr et al. 2017; Hinsley et al. 2017; Sardelis et al. 2017). This work has

demonstrated the lack of representation of women and people of colour as invited speakers and argued that a more intentional approach to improving diversity in this domain would help to provide role models for minorities and broaden the concept of "ideal worker" in geoscience (see Holmes et al. 2015b, p. 3) to include people of diverse backgrounds. Beyond geoscience, diversity scholars have shown that women often experience subtle forms of sexism and incivility at conferences (Settles and O'Connor 2014; Biernat and Hawley 2017; Biggs et al. 2017), and that collectively these experiences affect women's intentions to pursue a career in their scientific field of interest (Ratliff 2012). Women of colour were found to be significantly more likely to miss professional events such as conferences because they feel unsafe, resulting in lost career opportunities (Clancy et al. 2017).

The present study uses structured observations from a Canadian geoscience conference to analyse the participation of the Canadian geoscientific community across conference sessions and to observe behaviours within the conference itself. The conference—the Canadian Geophysical Union annual meeting—is one of the largest academic geoscience gatherings in Canada (with 516 registrants in 2017) and is likely reflective of dynamics in the broader North American geoscience community. This study examines how multiple aspects of identity (gender, ethnicity, career stage) affect conference participation, recognizing that multiple forms of power and bias may operate simultaneously to exclude particular bodies and identities from conference spaces. Although the observational nature of this study means that only crude indicators of identity (gender and ethnicity) are possible, limiting our ability to undertake a nuanced analysis, we believe attention to these aspects of identity is important given evidence that women of colour often face double barriers in STEM (Ong et al. 2011).

Drawing on our results, we advance three interrelated arguments. First, the quantitative benchmarking of conference participation can be used to pose and answer questions about the inclusiveness of different fields in geoscience. Comparing where women and people of colour are more and less likely to be within these fields allows us to identify which environments may be more hospitable to diversity and ask why. Second, the content of conference presentations can tell us who is doing what within a given discipline, helping to understand the division of scientific labour in the geosciences. This information provides greater visibility into which elements of the scientific enterprise are accessible to women and people of colour and which elements may need deeper introspection. Third, examination of conference behaviours can reveal the mechanisms through which aspiring geoscientists confirm a sense of self, which can offer new priorities for diversity policy and practice.

The next section provides an overview of the conference, followed by a description of the methodology used in this study and the limitations of the dataset. "Benchmarking diversity in a Canadian geoscience conference" illustrates the disparity in conference participation across disciplinary sections, a disparity that would be obscured by looking at conference-scale participation numbers alone. "Characterising intellectual diversity" explores patterns in the use of different scientific methods and the framing of scientific contributions across conference demographics. Finally, "Session climates and behavioural dynamics" investigates how men, women, and people of colour experience differently composed and behaved audiences, and we consider whether a "chilly climate" (Ratliff 2012, p. 28) for women and minorities exists in Canadian geoscience. The concluding section synthesizes the implications of our analysis for diversity research and policy.

Conference overview

The Canadian Geophysical Union's annual meeting is primarily attended by academic participants, mainly from Canada and the US, and it is often partnered with a related organization. In 2017 the joint Canadian Geophysical Union and Canadian Society of Agricultural and Forest Meteorology (CGU-CSAFM) conference took place 28–31 May 2017. The 2017 conference attracted 516 attendees

and consisted of seven disciplinary sections: Biogeosciences, CSAFM, Hydrology, Earth Surface, Geodesy, Solid Earth, and Joint/Interdisciplinary. A total of sixty-four 90-min sessions generally consisting of six presentations each were held across all sections, with Hydrology and Earth Surface collectively containing more than half of all sessions. Topics with more than six speakers were therefore spread across multiple sessions (e.g., H06A and H06B for two sessions within the same Hydrology topic). A summary of sessions by section is shown in Table 1. Oral presentations and plenary lectures occurred across seven different rooms in four buildings, with room capacity ranging from about 50 to 350 people. Within each room, up to four sessions occurred each day.

Methodology

For this study we collected conference registration data and generated in-conference observations of presenter demographics, presentation content, and presenter and audience behaviours.

Data collection

Registration database

In the online registration website for the CGU-CSAFM conference, registrants were asked (on a voluntary basis) to indicate their self-identified gender, career stage, and career sector. This database of conference registrants enabled analysis of the composition of overall conference attendees, including both presenters and non-presenters. For attendees who registered physically at the conference (41 individuals), demographic details were not collected.

In-session observations

Structured observation templates were used by pairs of observers who attended four parallel sessions across the duration of the conference. Data were collected for 47 out of 64 conference sessions and 256 of 337 total presentations. With the exception of a few logistical rearrangements, the sample of observed sessions was chosen using a random number generator. The disciplinary breakdown of observed presentations is within 2% of the disciplinary breakdown of presentations for the conference as a whole.

Table 1. Overview of conference demographics by section.

	Sessions (e.g., H01A)				
Disciplinary section	Number of sessions	Number of sessions with observations	Number of oral presentations[a]	Female presenters (%)[a]	Presenters of colour (%)[a]
Hydrology (H)	24	19	105	20	25
Earth Surface (ES)	16	13	65	29	6
Biogeosciences (B)	9	5	33	33	9
Solid Earth (SE)	9	5	29	38	41
Canadian Society for Agricultural and Forest Meteorology (CSAFM)	4	3	15	47	27
Geodesy (G)	1	1	5	40	60
Joint (J)	1	1	4	25	25
Total	64	47	256	28[b]	21[b]

[a]Presenter numbers are derived only from sessions observed.
[b]Values correspond to average percentage across disciplines.

In each session observed, one researcher collected observations about the substance of the presentations (e.g., visual content, research methods, intellectual contributions), and a second researcher made structural observations about the presenter demographics (gender, ethnic affiliation, career stage) and the behavioural dynamics of the room (e.g., total audience size, number of women in the audience, length and type of questions asked). Our eight-person research team consisted of both social and geophysical scientists, and to distribute disciplinary bias the geophysical specialists were paired with non-specialists. In sessions where one of the observers' research interests were being presented, that observer was tasked with making structural observations rather than evaluating the substance of the presentation.

Templates were used for note taking to ensure the systematic and consistent identification of substantive and structural elements across presentations (see also Campbell et al. 2014; Corson et al. 2014). The templates used are included in **Fig. S1**. Following Corson et al. (2014), the observation templates were built through iterative brainstorming workshops among the research team, guided by intensive reading on social science methodology, and refined through conversation with social science faculty at our university. Draft templates were tested on departmental and faculty public seminars and were subject to minor refinement midway through the first day of the conference after being tested in the first block of sessions. The final templates embody a balance between (*i*) seeking comparable observations (using check-boxes for prescribed categories), (*ii*) allowing qualitative descriptions for unique observations, and (*iii*) reducing cognitive demand for the observers. From the template observations a data set was compiled that included demographic, substantive, and behavioural observations for each presentation attended by the research team.

Although the observers did not attend poster sessions, a database of poster author gender was compiled based on the online conference program. Publicly searchable author information was also included in the benchmarking analysis.

A note on methodological limitations

We acknowledge an irreducible (and, for some topics, significant) level of subjectivity in terms of how observers described and classified their observations in the conference, which poses challenges for comparison. To address this we (*i*) endeavored to use objective metrics such as time, audience counts, and presence/absence tick boxes; (*ii*) made observations in stratified pairs to enable cross-validation of certain variables and reduce disciplinary bias; and (*iii*) discussed and revised our observational habits before, during, and after the conference to increase reliability and replication of categorical observations.

In this study we employed binary categories of gender and ethnicity, and we visually identified and classified people into these categories. The category people of colour therefore refers to individuals who appeared non-white (including presenters of Middle Eastern, Indigenous, Latinx, Asian, and African descent), and does not provide any information on presenters' country of birth or education. Similar categories have been employed in other studies (see Ong et al. 2011). We recognize that binary concepts of identity may produce a feeling of exclusion for persons who do not fit these binary categories of identity, and that person of colour is a crude indicator of people's lived experiences of cultural or racialized exclusion. Acknowledging these limitations, we feel that the reflexive use of these indicators for purposes of promoting diversity and inclusion is beneficial here.

This paper focuses solely on the formal spaces of an academic conference. However, social events, coffee breaks, and informal networking are all important places where both positive and negative conference experiences are produced. The ways in which these informal spaces and practices contribute to the culture and climate of the earth sciences deserve further investigation but are beyond the scope of this study.

In general, data are reported at a population scale, and we do not statistically compare data between disciplinary sections because of low sample sizes in some sections. Where a statistical evaluation of data was possible and provided additional insight, analysis was performed using a Kruskal–Wallis one-way ANOVA.

Benchmarking diversity in a Canadian geoscience conference

Combining registration data and observations made in the oral presentations enables the description of the composition and character of the geoscience community as represented by this conference. This provides a quantitative benchmark against which future conference participation may be compared, and compares participation in this context against other conferences, run by other societies, in other countries, and in other disciplines. This section explores the demographic characteristics of the CGU-CSAFM conference at the level of overall registration as well as within the disciplinary sections.

Who attended? A demographic breakdown of conference registration

A total of 516 people registered for the conference (including 1-day attendees). Registrants were asked to self-report their gender, institutional affiliation, and career stage; however, information on registrant ethnicity was not collected. Women comprised just over a third (36%) of the 84% of registrants who indicated their gender. This number is slightly higher than the largest North American geoscience society, the American Geophysical Union, which has a membership of around 60 000 and reports an increase in female membership from 15% in 2000 to 27% in 2015 (Leinen 2016). It is also higher than for the CSAFM's general membership, wherein women constitute 22% of the 117 email listserv members and 30% of the 30 current members in good standing (A. Glenn, personal communication, 2017). Membership data for CGU were not available. The representation of women at the CGU-CSAFM 2017 conference is also similar to the US geoscience workforce and higher than observed in the Canadian workforce. Wilson (2017) reported that women made up 34% of the geoscientists in the US, whereas Canadian census data from 2011 shows that women make up 23% of employed geoscientists (Statistics Canada 2011).

Figure 1 shows the distribution of conference registrants by gender and career stage. Overall, PhD students were the largest group of conference registrants (25%), whereas undergraduate students were the smallest group (3%). Considering the distribution of career stages for women and men reveals diverging trends; past the undergraduate level, the percentage of women declines steadily with career stage, with the most female attendees at the Master's and PhD levels (34% and 24%, respectively) and the least at the senior level (7%). Comparatively, the greatest number of male attendees were at both the PhD and senior levels (26% and 24%, respectively), indicating that men at the conference are represented more consistently throughout all career stages. Similar trends were observed in the career stages of oral presenters (**Fig. S2**). Although a relatively junior female geoscientific workforce may be interpreted as reflecting an increasing interest from females in geoscience careers, a significant body of research has repeatedly demonstrated that increased participation at the graduate level has not translated into proportionate representation in senior positions in STEM fields (Alper 1993; Griffith 2010; Glass 2015). This decreasing representation of women at higher career stages is prevalent in geoscience (Nentwich 2010; Glass 2015; Thornbush 2016) and STEM fields more broadly (e.g., Huntoon and Lane 2007; Levine et al. 2007). This pattern has been described as a "leaky pipeline" (Alper 1993; Holmes et al. 2015b) wherein women for various reasons opt out of the typical academic career pathway, leading to fewer women at highest ranks in the academy.

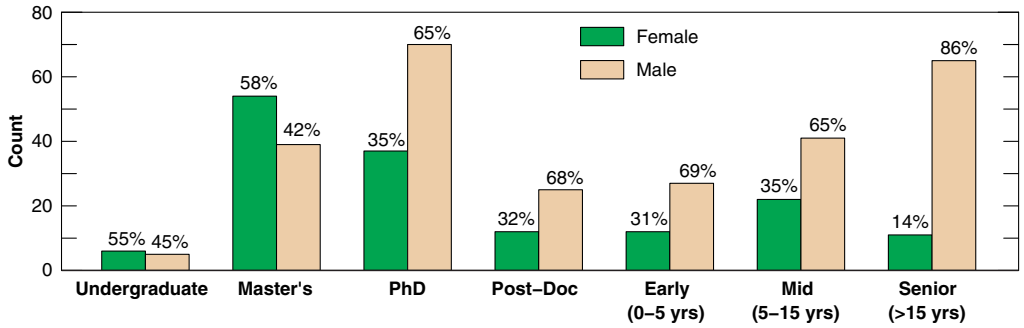

Fig. 1. Count of conference registrants by career stage. Note that career stage was self-identified by the registrants upon conference registration. Percentages correspond to fractions within each career stage.

The majority of conference registrants who volunteered their demographic information originated from the academic sector (83%). Only 9% of these registrants identified as government affiliated and 5% as affiliated with the private sector. The dominance of the academic sector at this conference likely reflects how this meeting is traditionally pitched towards highlighting research advances, attracting a specific subset of geoscientists in Canada. Professional and industry conferences may provide a useful comparator to see whether ethnic minorities are better represented up the career ladder in nonacademic organizations.

Who presented where? The demographics of the presenters

A total of 337 oral presentations (excluding plenaries) were given at the conference, and 149 posters were presented. Conference attendee demographics by presentation type are shown in Table 2. Based on the conference program, 39% of poster presenters were female and 62% were students. Of the 256 oral presentations we observed, 28% of speakers were female and 39% were students. Relative to the registration numbers, women were over-represented as poster presenters and under-represented as oral presenters. Although women were over-represented at the student level (62% of women registered as students) at the conference, this does not appear to explain the higher proportion of women presenting posters: 41% of all female student presenters (oral or poster) presented posters compared with 46% of male students. Hence, women in more advanced career stages are either more likely to ask for poster slots overall or are disproportionately assigned posters relative to men. Data about the ethnicity of poster presenters were not collected.

Table 2. Demographic breakdown of conference attendees giving oral, invited, and poster presentations.

Presentation type	Number of presenters	Number of female presenters	Female presenters (%)	Number of male presenters	Male presenters (%)	Number of student presenters	Student presenters (%)[a]	Number of female students	Female students (%)	Number of male students	Male students (%)
Poster	149	57	39	92	61	92	62	40	70	52	57
Oral[b]	256	72	28	184	72	100	39	39	54	61	33
Invited oral[c]	21	4[c]	19[c]	17	81	NA	NA	NA	NA	NA	NA

[a]Includes undergraduate, Master's, and PhD students.
[b]Includes invited speakers.
[c]Does not include plenary talks. There were four plenaries in total, two of which were given by women.

Invited speaker positions at conferences celebrate the important work of individuals and also expose that researcher's work to a wider audience. At the CGU-CSAFM conference, two of the four plenary lectures were given by women; however, only four of the 21 invited non-plenary speakers (see **Table 2**) for the oral sessions were women, a proportion similarly observed in ecology and biology symposia (Schroeder et al. 2013; Farr et al. 2017).

Analysis of section-level data found profound differences in diversity among the disciplines of geoscience represented at the conference (**Fig. 2**). Although women constituted nearly half of the presenters in smaller sections such as CSAFM, in the more populous sections, such as Hydrology and Earth Surface, women made up only one in every five presenters (**Fig. 2a**). That women made up so few of the Hydrology presenters is significant because, with 41% of all speakers, the Hydrology section was also the largest section at the conference. Our findings corroborate other studies that identify how women are particularly poorly represented in Hydrology relative to the Biogeosciences and other geoscience disciplines, indicating persistent disciplinary differences (Luzzadder-Beach and Macfarlane 2000; Holmes and O'Connell 2003).

Across all sections, people of colour composed 21% of all presenters and 19% of female presenters. This suggests that people of colour, in particular women of colour, were poorly represented at this conference, just as they are in STEM in the US (Williams et al. 2014). Data are not available to compare these proportions to other geoscience conferences; however, the geosciences have the lowest ethnic diversity of any STEM discipline (Huntoon and Lane 2007; Williams et al. 2014; Clancy et al. 2017). **Figure 2b** shows that differences in the participation of people of colour between sections are

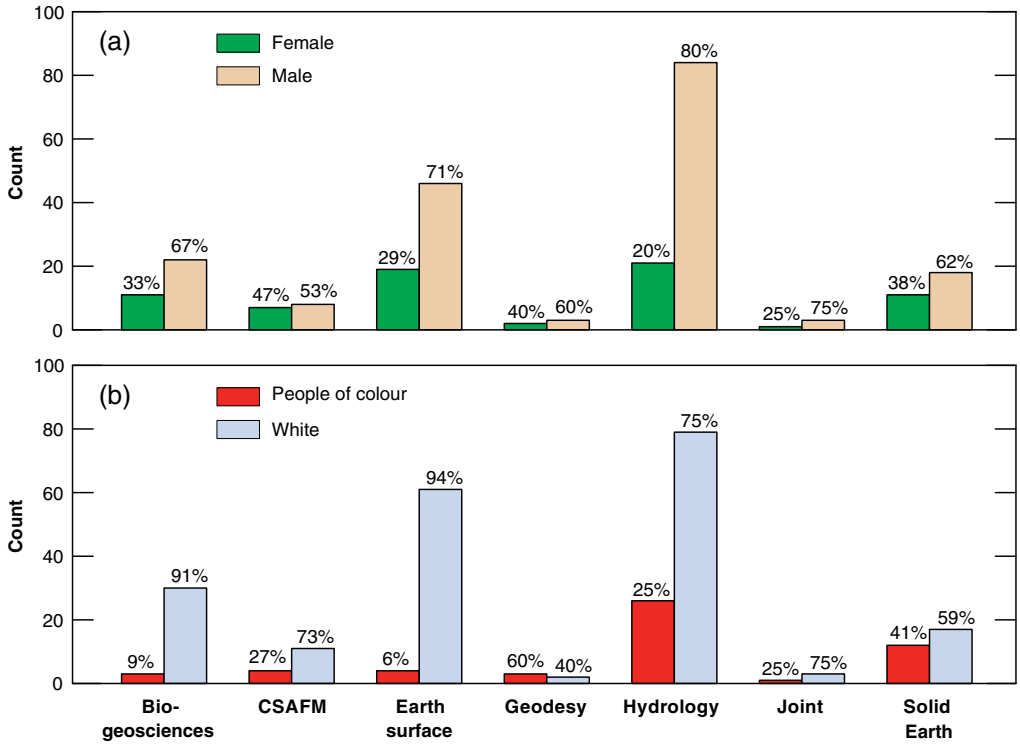

Fig. 2. Presenters by geoscience section divided by gender (a) and ethnic affiliation (b). Count numbers correspond to observed presentations rather than entire list of presenters and annotated percentages to the breakdown within each geoscience section.

more pronounced than those of gender. At the upper end, people of colour comprised up to 60% of speakers in Geodesy (one session) and 41% in Solid Earth (nine sessions), although both of these disciplinary sections contained fewer presenters overall (see **Table 1**). Conversely, sections with very low proportions of people of colour, such as Biogeosciences (9%) and Earth Surface (6%), tended to have greater total numbers of presenters.

Session-level differences illustrate the effects of this unevenness. Although 36% of registrants and 28% of speakers at the conference were female, a quarter of conference sessions had no female presenters at all. Similarly, although 21% of conference presenters were people of colour, almost a quarter of sessions (23%) had no people of colour presenting, and in five sessions more than 50% of the presenters were people of colour. Although these numbers might be expected statistically speaking, materially this lack of representation produces conference spaces where women and minorities, although present in the audience, are absent from the discussion on stage.

Summary

Analysing both the registration and presenter data revealed that despite higher registration numbers at the CGU-CSAFM conference than reflective of the wider geoscience community, women were under-represented as oral and invited presenters and over-represented as poster presenters. Given that oral and invited presentations tend to be more highly valued and reach a greater audience, women's contributions are thus less visible in the more prominent fora of the conference.

Women and people of colour were also unevenly distributed across disciplines, and were better represented as presenters in the smaller sections such as CSAFM. As a result, larger, less diverse sections, such as Hydrology and Earth Surface, had numerous sessions that contained no women presenters or no people of colour presenting. As will be discussed later in this paper, sessions without women and people of colour presenting can exhibit a distinct climate that makes certain people feel excluded.

In 2001 in the US, only 3% of Master's and 5% of PhD graduates in the geosciences were members of under-represented groups (ethnic and other minorities, NSF 2001), spurring widespread government-funded efforts to increase diversity in the geosciences. Although attempts to increase the number of women in the geosciences have been modestly successful (for example, between 2004 and 2014, the share of Earth Science PhDs earned by women increased from 33% to 43%), the same trend has not been observed across other under-represented groups; the proportion of white PhD graduates remained constant from 2004 to 2014 (Falkenheim et al. 2017).

Demographic data from conferences provides numbers by which efforts to increase diversity can be evaluated. Comparing disciplines within a conference can help to elucidate where women and people of colour are better represented, whereas registrant-level data can be used to compare diversity between different types of conferences and between geographic locations. Although meetings of the CGU tend to attract a more academic audience, it would be interesting to examine how the demographics of a more industry-affiliated conference may compare.

Characterising intellectual diversity

Although many studies have examined the participation of women and people of colour in science in aggregate, few have examined how their participation varies in terms of the types of research they undertake (see Luzzadder-Beach and Macfarlane 2000). If we want to achieve diverse representation across the geosciences, we need to not only make efforts to increase absolute numbers of women and people of colour, but also to value their distinctive contributions. However, although difference should be celebrated, previous research has highlighted that this can result in some researchers being excluded from particular fields. For example, women are reported as under-rating their own

performance in mathematics due to learned biases (Skibba 2016), feeling alienated from computer sciences due to an increasingly masculine culture (Cheryan et al. 2017), and lacking access to laboratories due to funding (Luzzadder-Beach and Macfarlane 2000). By analysing how intellectual diversity relates to demographic diversity, we can identify whether different social groups tend to make different types of scientific contributions, use different methods, and connect their work to society in different ways. Here our aim is to both celebrate differences in strengths and interests as well as to identify existing under-representation in particular fields as an area of collective concern and remedial action.

The intellectual diversity of oral presentations was captured three key ways: (*i*) according to the methods used in each study, (*ii*) based on the type of contribution each study made to its field of research, and (*iii*) from the presenter's articulation of the real-world significance of their research (see **Fig. S1**). The observation template included tick-box categories for primary methods, contribution types, and clarity of real-world justification. These categories were created through discussion among the research team, drawing on the collective experiences of the team with geoscience presentations as well as their detailed knowledge of the conference program and abstracts.

Observers systematically recorded each presentation's main method(s), contribution type(s), and real-world justification according to the predefined categories, and provided a short description of the study's scientific and real-world contribution(s). The freehand descriptions of each presentation's contributions were later coded and compared with the categorical data to check for consistency in categorisation and to identify any unexpected contribution types. The data were analysed to identify key trends in research methods and contribution types and broken down by presenter demographic variables (gender, career stage, ethnic affiliation, sector) and session type.

Overview of intellectual diversity in oral presentations

The data reveal the intellectual dominance of specific methods and contribution types in the geosciences, but also highlight that this dominance varies by section. For example, field methods were more common in the Biogeosciences, CSAFM, and Earth Surface, than in Hydrology, Solid Earth, Geodesy, and Joint (**Table 3**). Modelling, in contrast, is most prominent in Geodesy, Hydrology, and Solid Earth and far less common in other section types. Remote sensing was commonly used in only the Solid Earth and Joint sessions (which included a named remote sensing session). Laboratory research and social methods stand out as approaches that are not commonly utilised in the geosciences and, therefore, as opportunities to improve intellectual diversity.

Similar trends are observed in the intellectual contribution data. Field methods remain prominent, with 44% of all presentations contributing "new observational data". Other common contribution types were "new method" (31%) or "applied solution" (18%); all other categories occurred in fewer than 15% of presentations (**Fig. 3**). Disciplinary groupings of contributions are also evident, with "new observational data" standing out as the dominant contribution type in Biogeosciences, CSAFM, and Earth Surface sessions. "Applied solutions" were also common in Earth Surface and Biogeosciences sessions. However, in Hydrology, Solid Earth, and Geodesy, "new method" and (or) "reanalysis of existing data" were much more common, competing with "new observational data" as the key contribution type.

The majority of presenters connected their research to real-world issues in a substantive way, with just 26% providing no justification. Justifications ranged from "vague" assertions of potential applications (e.g. findings might have implications for drainage water chemistry), to "clear" descriptions of how the research enhances understanding of a specific problem or solution (e.g., earthquake early warning systems).

Table 3. Percentage of presenters using a specific research method, by disciplinary section, gender, ethnic affiliation, and career stage.

	Total number of presentations	Research method (%)[a]				
		Field methods	Lab methods	Remote data collection	Modelling	Social science
Disciplinary section						
Biogeosciences	33	82	18	9	24	0
Canadian Society of Agricultural and Forest Meteorology	15	87	7	7	13	0
Earth Surface	64	56	11	27	27	6
Hydrology	102	44	8	20	61	3
Solid Earth	29	45	7	48	48	0
Geodesy	5	0	0	20	100	0
Joint	4	0	0	100	25	0
Gender of presenter						
Female	72	64	14	17	39	3
Male	180	49	7	24	42	3
Ethnic affiliation of presenter						
Person of colour	52	40	10	23	52	4
White	200	60	11	25	38	4
Career stage of presenter						
Student	98	56	11	18	47	2
Early career	59	51	8	25	51	5
Mid-career	59	46	5	27	41	2
Late career	31	68	16	32	26	0
Retired	3	0	0	0	33	33

Note: Total $n = 252$ (data on intellectual contribution was not collected for four presentations).
[a]Many presenters described using more than one type of method, therefore the percentages do not sum to 100%.

Gendered intellectual contributions

Results reveal notable gender differences in the methods used, intellectual contributions made, and real-world justifications articulated by presenters (Table 3). Higher proportions of women use field and lab methods relative to men, and accordingly, contribute new observational and experimental data more frequently than men. In contrast, remote sensing and modelling methods are slightly male-dominated. However, the gendered use of methods varies by section, with Earth Surface sessions containing greater percentages of women using modelling (37% female vs. 22% male) and greater male use of field methods (53% female vs. 58% male). This variability suggests that the gendered differences indicated by our results may be further differentiated across specific types of methods (e.g., numerical vs. statistical modelling)—nuances that are not reflected in our broad method categories.

Comparing intellectual contributions between men and women showed that "new observational data" were the most common contributions for both genders (Fig. 3). However, applied solutions are almost twice as common among female presenters compared with men, which is notable because

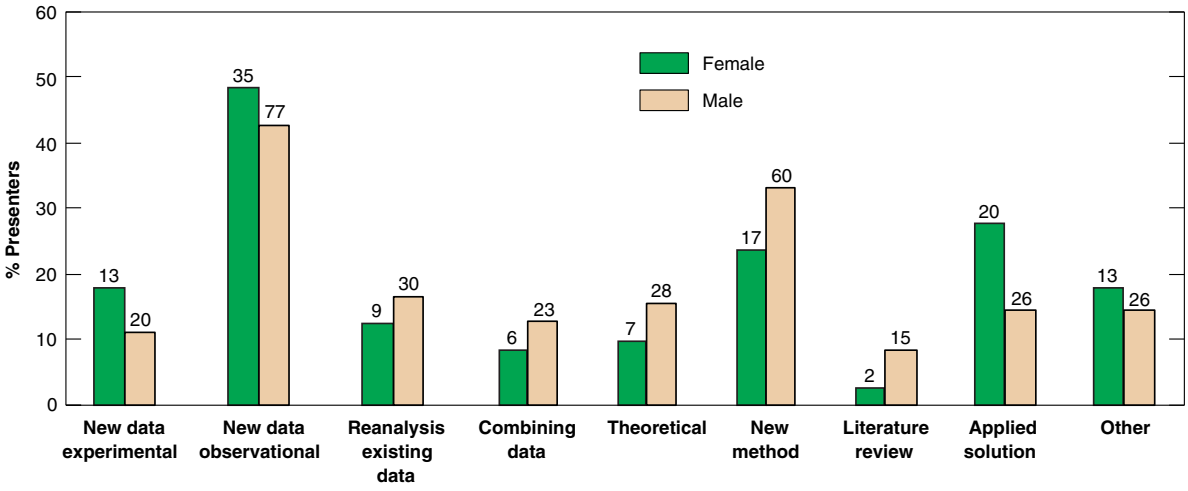

Fig. 3. Percentage of female ($n = 72$) and male ($n = 180$) presenters by type of intellectual contribution. Many presenters made more than one type of contribution. Numbers above bars correspond to count of presenters making a given intellectual contribution.

applied sessions drew audiences with the highest percentage of females. The relative dominance of women in the applied solutions category is consistent across all disciplines (with the exception of Geodesy and Joint sessions, where 1 and 0 presenters contributed an applied solution respectively), although the degree of dominance differs. Men are more likely to contribute a new method, especially in CSAFM, Hydrology, and Solid Earth, and to make data- and theoretical/literature-based contributions.

The prominence of applied solutions among female presenters is also reflected in the real-world justification data (see Fig. S4). A higher proportion of female presenters provided a real-world justification for their research relative to male presenters (80% vs. 72%), and a higher proportion of justifications by women were recorded as "clear". This gender difference appears to exist across career stage, sector, and disciplinary section, although the size of the justification gap varies. For example, Fig. 4 illustrates that in disciplines with above average rates of real-world justifications (e.g., Biogeosciences), a substantially larger proportion of female presenters provided a vague or clear justification for their research. Among Hydrology and Solid Earth presentations, however, women and men both communicated a real-world justification less frequently and at similar rates.

Intellectual contributions and ethnicity

Our findings also indicate that the use of methods, intellectual contributions, and real-world justifications differ substantially between people of colour and white presenters, and with the opposite trend of gender differences. For example, 52% of people of colour use modelling as a primary method, which is considerably more than white presenters (Table 3). People of colour also have markedly lower representation in field methods but use remote sensing and lab methods with similar frequency to white presenters.

The intellectual contributions of people of colour also differ substantially from those of white presenters. For this group, new methods are the most common intellectual contribution, followed by new observational data and reanalysis of existing data. As illustrated in Fig. 5, applied solutions (which were common among female presenters in general) are notably less common among people of colour. Similarly, people of colour provided a real-world justification for their research less frequently than white presenters (60% vs. 78%, see Fig. S4).

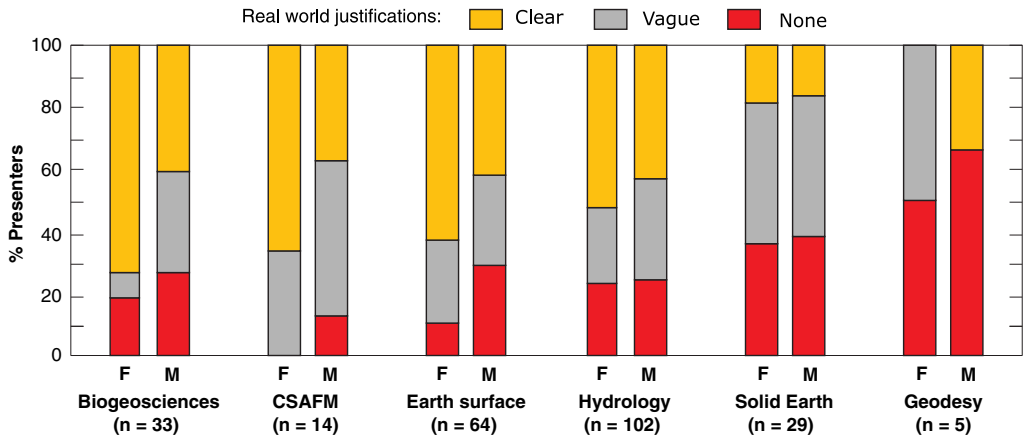

Fig. 4. Percentage of presenters who provided a real-world justification for their research, broken down by section and gender.

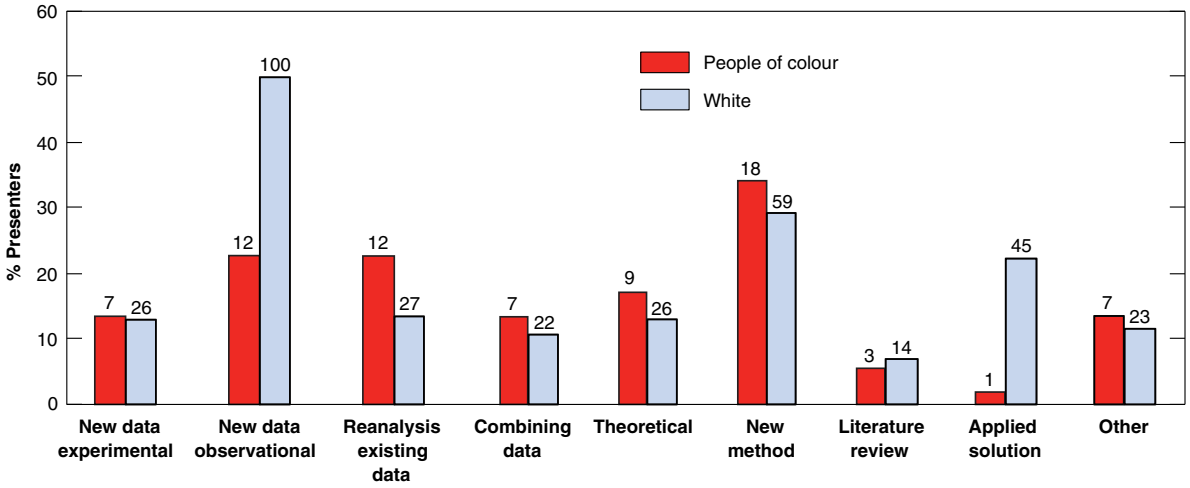

Fig. 5. Percentage of presenters identified as people of colour ($n = 52$) and white ($n = 200$) by type of intellectual contribution. Many presenters made more than one type of contribution. Numbers above bars correspond to count of presenters making a given intellectual contribution.

Intellectual contribution and career stage

Analysis of the intellectual diversity data revealed mixed relationships with career stage. Although the use of methods and real-world justifications showed clear differences according to career stage, contribution types did not. When analysed by method, the use of remote sensing increases consistently with the presenter's career stage, from 18% of students and 25% early-career scientists to 27% of mid-career and 32% of late-career scientists. In contrast, modelling is more common among student (47%) and early career (51%) scientists compared with mid-career (41%) and late-career (32%) scientists, suggesting that interest in modelling may be increasing generationally.

The career stage of the presenter does not clearly affect the contribution type. New observational data, new method, and applied solution are the dominant contribution types across all career stages, with the exception of early-career presenters who are more likely to make a theoretical contribution or

perform a reanalysis than provide an applied solution. Students are much less likely to make theoretical or literature review contributions than other career stages, but they are more likely to justify their research with reference to real-world problems. The proportion of presenters who did identify a real-world justification for their research generally decreases with career stage, from 22% among students to 35% among late-career presenters (see **Fig. S4**).

Summary

Although geoscience methods and contributions are changing with the introduction of new modelling and quantitative techniques, fieldwork and instrumental campaigns remain mainstays of geoscience research (see also Luzzadder-Beach and Macfarlane 2000). The popularity of geoscience methods and contribution types across different demographics suggests that seeking demographic diversity can foster increased intellectual diversity within geoscience conferences. For example, women were responsible for a large proportion of the applied solution studies presented at the conference (an otherwise less common contribution type) and were more likely to articulate the real-world significance of their research. Similarly, a larger proportion of people of colour contributed modelling studies and proposed new methods than white scientists. Students also contributed to the large number of presentations using modelling, whereas presenters from later career stages were responsible for the few, but important, presentations on theoretically focused work. Drawing attention to particular groups' distinctive intellectual contributions is one way of increasing the visibility of otherwise marginalised groups within the geosciences and actively valuing a diverse scholarly community. This suggestion mirrors Etzkowitz et al.'s (2008) observation that women's leadership in marginal, but growing, fields is one way in which female participation in science has grown over time. Given the negative consequences of a lack of relatable intellectual role models on student confidence (Shen 2013), celebration of the intellectual contributions of marginalised groups is likely to be important in encouraging increased participation by these groups into the future.

Scholarly areas in which women, people of colour, and students are under-represented relative to the wider geoscience community can and should be identified and potential barriers examined. Women's use of remote sensing and data analysis contributions are notably lower proportionally than men's, whereas participation in fieldwork-based research by people of colour is significantly lower than that of white presenters. This may in part reflect differences in interest, but much research has shown that differential access to research resources and inherent biases and cultural norms (producing a chilly climate) are often also responsible for pushing people to opt out of a scientific field (see Holmes 2015b; Cheryan et al. 2017; Clancy et al. 2017). By characterising the division of scientific labour in geoscience, scientists and administrators can ask why such differences exist in key areas and make efforts to remedy any such factors in operation. Modelling, for example, increases in popularity with earlier career stages, suggesting it is the next big thing. If modelling is indeed increasing in popularity and prestige in geoscience, then any gender gap here is worth significant investigation and remedial effort. Faculty leadership and mentorship are widely recognized as important supporting mechanisms for encouraging women and people of colour to persist and succeed in fields in which they have been traditionally under-represented (Ong et al. 2011; Thornbush 2016). In addition to highlighting hotspots of difference, characterising the intellectual diversity of geoscience can also indicate progress on past gaps; in contrast to evidence that women had less access to labs and to the field (Luzzadder-Beach and Macfarlane 2000; see also Carey et al. 2016), our results show women are now participating in these areas in higher proportions than men, although this does not necessarily mean that these women do not still face significant barriers within these scientific areas.

Finally, the intellectual contribution profiles of women and people of colour differ in sometimes opposite ways, and this should be recognized in diversity strategies. Although field methods are used proportionately more by women than men, a significantly lower proportion of people of colour use

field methods, as they instead tend to use modelling approaches (although there is likely significant variation within the broad category of people of colour). Similarly, a high proportion of women contribute applied solutions, whereas this is an uncommon contribution type among people of colour. Since different under-represented minorities appear to contribute to intellectual diversity in different ways, it is important that efforts to re-value intellectual diversity do not promote one demographic at the expense of another (see Ong et al. 2011).

Session climates and behavioural dynamics

Conferences function as social arenas that can reproduce broader societal biases and assumptions about what type of person is a competent and legitimate scientist (Ratliff 2012; Settles and O'Connor 2014; Sardelis and Drew 2016, Hinsley et al. 2017). This does not usually happen through overt displays of sexism, racism, or intolerance, but rather through the accumulation of largely subtle behaviours and interactions (e.g., keynote speaker selection, audience etiquette, question tone) that have the effect of producing a chilly climate for minority geo/scientists who can feel that they do not belong (see Holmes 2015b). The ongoing promotion of codes of conduct for academic conferences attests to a continuing differential of experience of conferences (Martin 2014; Begiato et al. 2015; Sardelis et al. 2017).

This section explores whether such a chilly climate is evident in our Canadian geoscience conference and what its composition might be. Our aim is to identify how behaviours observed or experienced at a conference might affect an emerging researcher's sense of belonging in geoscience. This analysis draws on both the registration database and the presentation-scale observations. In the presentations attended, observers made systematic categorical (tick box and ranking) and open qualitative observations about the demographics and behaviours of conference session participants (audience, presenters, chairs). Sessions that appear to deviate from broad scale trends are investigated in more detail, drawing on qualitative observations from those sessions.

Influence of session conveners on presenter composition

Session conveners exert first-order influence on who presents in a session as they solicit speakers and decide on the allocation of oral presentations and posters. If the identity of a convener has an effect on the demographics of their network, this should be evident from conference session demographics. Although we did not collect data on convener ethnicity, data on convener gender were collected and are explored here.

The 47 observed sessions fell within 33 thematic topics, each with distinct conveners. Of these topics, 16 had one or more female conveners. Similar to previous studies (e.g., Sardelis and Drew 2016), we find that the involvement of at least one female session convener results in significantly ($p < 0.05$) higher percentages of female presenters in a session (averages of 38% vs. 23% in sessions with no female conveners). The impact of female conveners was particularly pronounced within Earth Surface where the involvement of female conveners increased the percentage of female presenters from an average of 17% to 50%.

Although there are likely multiple explanations for these results, they confirm that securing female conveners appears to be an effective diversification strategy for recruiting more female presenters. We encourage interested researchers to reflect on the choices they make in their own networks and consider how we collectively might make future conference sessions more diverse.

How presenters behave

Oral presenters at a conference play a significant role in setting expectations (via role models) about whose time and expertise should be accorded value and respect. We investigate how presenters kept

to time (or not) and how the use of language varied across the conference, to consider what this might mean for student or minority scientists looking to/for role models within geoscience.

Who keeps to time?

The amount of time allotted to each presentation at the conference was 15 min, with the expectation that this included time for questions. Timekeeping was enforced by a student volunteer using visual cues. The length of each presentation was timed with a stopwatch and recorded in our observation templates. Across the conference, there was no statistically significant difference in the average length of presentations between men and women or between people of colour and white presenters. However, the length of presentation increased with advancing career stage (Fig. 6), and student and early-career presenters had significantly shorter presentations than mid- and late-career presenters ($p < 0.05$).

Although the majority of presenters adhered to the 15-min time slots, there were 17 observed presentations that went overtime, 13 of which were by male presenters. Of these overtime presentations, 10 were more than a minute over time (>16 min long), nine of which were given by men. One of the male speakers who ran overtime was the chair of that session, and in another case the chair (also male) was a named co-author on the presentation and did not enforce the time. In another instance, the presenter repeatedly refused to acknowledge time enforcement despite multiple attempts by the chair to bring an end to the presentation. These examples, together with the trend of increasing presentation length with career stage, suggest the importance of power dynamics in shaping presenter behaviours, where dominant presenters feel more comfortable bending rules to suit themselves, often at the expense of other presenters (e.g., students).

Use of language

To examine how language affects the atmosphere of a session, our observation templates included prompts for open notes on the use of formal and informal language. Jokes were used more frequently by men (observed in 22% of presentations vs. 10% of presentations by women). The use of jokes indicates a level of comfort and familiarity and can be useful tools for engaging an audience and creating a casual atmosphere. However, particular types of jokes and behaviours (i.e., racialized, sexualized) are socially charged and carry loaded cues about belonging to a group. Such identity cues—"socially symbolic [objects] that embody and communicate group member stereotypes to others" (Cheryan et al. 2009, p. 1046; see also Cheryan et al. 2017)—can make some people feel uncomfortable, especially when they are already marginalized within a community (e.g., Biernat and Hawley 2017).

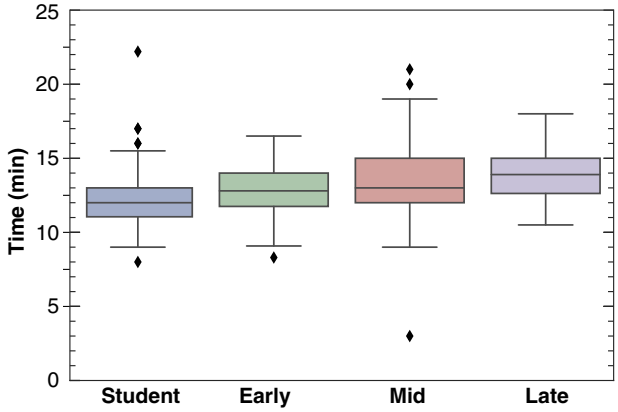

Fig. 6. Presentation duration by career stage. The time allotted for each presentation was 15 min, with the exception of invited presentations, which were granted between 20 and 30 min.

We observed several of these types of identity cues in the 11 sessions that had no female presenters. Several jokes were made at the expense of others; in one instance a student, in another the presenter's wife (neither of whom were present), and in a third, of the chair when time signalling was enforced. Other jokes relied upon non-universal conceptions of methods and nature, such as the term "geo-porn". Beyond jokes, there were other incidents of gendered language in sessions with no female presenters. One presenter referred to the audience as "you guys" throughout his talk (despite half the audience being women). In another presentation, a female graduate student was reported to have "gone sideways" and delayed the progress of the research.

In the remaining 36 sessions in which one or more women presented, there were similar examples of gendered comments (for example, assuming the gender of a hypothetical worker) or aggressive behaviour (such as harassing a female volunteer about timekeeping or telling people accidentally entering in the middle of the talk to "get out"), but they were less common. There were also three incidents of ignoring or arguing with timekeeping (two by males and one by a female presenter). Overall, however, our findings echo previous studies in suggesting that more diverse participation in a session promotes a more inclusive and respectful environment (Bear and Woolley 2011).

Who is in the audience, and how do they behave?

How attentive is the audience? Measuring levels of disturbance

An inattentive audience affects the experience of both the speaker (who may feel devalued), and the audience members (who learn from others' behaviour how to value the presenters' work). Our observation templates included prompts for noting (*i*) people entering and exiting the room during presentations, (*ii*) people talking, and (*iii*) people distracted by electronic devices. Each behaviour was given a score of 0 (none), 1 (some), or 2 (a lot). To reduce the subjectivity in making these designations, observers compared their initial assessments from the first two session timeslots during lunchtime on the first day of the conference to calibrate their observation criteria. A research-team evaluation after the conference confirmed a general consistency in rating criteria.

A sum of the three scores was given to each presentation to provide an indicative measure of disturbance, with a maximum per-presentation score of six. Presentations by women had an average audience disturbance score of 1.93, which is higher than the average score for presentations by men (1.67), but this is not significant ($p = 0.059$). Sessions with no female presenters had the most attentive audiences, with a disturbance score significantly ($p < 0.01$) lower than in sessions with one or more female presenters (**Fig. 7**). The difference is also pronounced for people of colour ($p < 0.01$), who experienced average audience disturbance scores of 2.07 relative to 1.65 for white presenters. As the number of people of colour presenting within a session increased, the average disturbance scores also increased, particularly with regards to talking and technology use.

Audience composition: Who attends what?

Women represented 33% of audience members, similar in proportion to conference registrants. Audience demographics by section are shown in **Fig. S3**. At the session-scale female audience participation fluctuated significantly, ranging from 17% to 51%. As the number of women presenters increased within a session, the percentage of women in the audience also increased ($p < 0.005$). Outliers from this trend are a CSAFM session with 70% female presenters and 24% women in the audience, and 11 sessions with no female presenters and female presence in the audience ranging from 22% up to 37%.

To explore what might influence the wide range of female audience participation rates, we compared dynamics of the sessions with the five lowest percentages of women in the audience to sessions with the five highest. We looked for any commonalities that might suggest that sessions with high turnouts

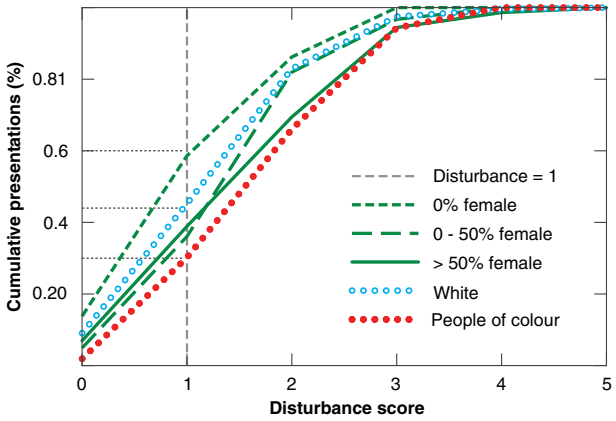

Fig. 7. Cumulative disturbance scores for sessions based on the demographics of presenters. Vertical dashed grey line represents disturbance scores of 1, and horizontal lines represent the intersection of disturbance score 1 with different demographic categories. For example, where the vertical line intercepts with the line for sessions without female presenters (small dashes, green), it is interpreted as saying 60% of presentations in these sessions had disturbance scores of 1 or below. This compares with presenters identified as people of colour for whom only 30% of presentations had disturbance scores of 1 or below.

of women in the audience had receptive or warm climates that might attract more women to that particular community of researchers. Of the sessions with low female turnout, 85% of the speakers were male, as opposed to 45% in sessions with high female turnout. Both high and low female turnout sessions had an equal mix of career stages and employer sector (public vs. industry), suggesting these variables are not responsible for this disparity.

When examining presentation style, slight differences emerge. Although observers frequently described both categories of sessions as "dry", "jargon-rich", and "technical", there were more observations of accessible language in sessions with high female turnout. Similar to findings above regarding intellectual diversity, presenters in these five female-dominated sessions provided real-world justification for the research more frequently than presenters in male-dominated sections.

Question and answer periods

The question and answer period during a conference can be helpful and invigorating, or alternatively deflating and disappointing for a presenter (e.g., see Begiato et al. 2015). For up to the first three questions of a given presentation, we recorded the length, tone, and types of questions asked of presenters to see whether and how question asking might contribute to a chilly climate for certain presenters. In the 240 15-min presentations (i.e., excluding 30-min invited presentations) we observed, 410 questions were recorded (**Tables 4** and **5** provides an overview of the question and answer (Q&A) period). There was little difference in the number of questions asked of presenters of either gender (an average around 1.75 questions for both men and women presenters). At the conference scale, men asked 80% of questions to all presenters, regardless of gender. Of all the questions observed, only 20% were asked by women, even though they composed, on average, 33% of the audience (a recent study by Hinsley et al. (2017) found similar results). Further, the number of questions asked by women is not significantly correlated with the percentage of women in the audience. This may be at least partly attributable to the high percentages of female attendants who are students; however, we did not have sufficient confidence in our career stage estimates of questions askers to assess that effect here. However, as **Tables 4** and **5** show, women were more likely to ask questions in female-dominated sessions. Nevertheless, of 410 questions there were only 23 instances of women asking questions of

Table 4. Overview of questions asked, by gender of questioner.

Presenter gender	Number of questions asked		
	Male questioner	Female questioner	Total
Male	228	59	287
Female	100	23	123
Total	328	82	410

Table 5. Overview of questions asked by gender of presenter.

Female presenters per session (%)	Total number of presentations[a]	Number of questions asked		Questions asked by women (%)
		Male questioner	Female questioner	
0	56	80	19	19
<50	103	162	30	16
>50	81	86	33	28
Total	240	328	82	20

[a]Includes only 15 minute talks.

women (6%), illustrating the frequently reported sensation of women being isolated in a man's world (Holmes and O'Connell 2003; Holmes 2015b).

One of the most striking differences between these session groups was observed in the Q&A period (Fig. S5). In the five male-dominated sessions, 14 "critical" or "argumentative" questions were observed, as well as three "condescending" ones, including one of which the asker "waved presenter off (literally)". Only three "argumentative" questions and one "condescending" question were observed in the five female-dominated session, as well as three complimentary comments. No complimentary comments were observed during the Q&A session of the male-dominated presentations.

Most of the 410 questions involved requesting additional information. Interruptions and repudiations were highest in the male-only sessions, where they made up 11% of all questions asked. They made up only 6% and 4% of questions in sessions with <50% and ≥50% female presenters, respectively. The person of colour status of the speaker had no discernable effect on the number of questions asked, although they were less likely to be repudiated by questioners or interrupted in their response.

Finally, we looked at the length of questions being asked. Most questions asked during the conference were <30 s in length. However, a total of 16 questions exceeded a minute in length, all of which were asked by men. Twelve of these questions were asked of male presenters, and four of female presenters.

Summary

Observations of in-conference behaviours can identify otherwise invisible components of the climate of sessions at a geoscience conference. Evidence from the CGU-CSAFM meeting illuminates several behaviours that contribute to chilly climates for women and people of colour in particular sessions: presenter behaviour that includes cues of belonging such as the use of gendered language, a higher tendency for men to take more time when giving a presentation or asking a question, higher levels

of audience distraction when women and people of colour (in particular) are presenting, and more aggressive questioning styles in male-dominated sessions.

These results confirm that a chilly climate is often part of the lived experience of people of colour and women at academic conferences (Settles and O'Connor 2014; Biggs et al. 2017). For student researchers (62% of female CGU-CSAFM attendees were students), their scientific interest in a particular field must be weighed against behaviours they have either experienced or think they might experience in particular research communities (Ratliff 2012). A choice to pursue a research career within a field whose ideal worker does not resemble one's self may require adopting those behaviours that reproduce its chilly climate (Katila and Meriläinen 1999). Otherwise, a researcher might choose to opt for a different discipline with a more welcoming climate, leave research altogether, or simply be less active in their research careers. We wonder, for example, whether previous chilly experiences at conferences might contribute to the apparent fact that women either opt for or are assigned more poster presentation slots rather than oral presentations.

To support the ongoing diversification of the geo/sciences, we invite individual members of the community to cultivate awareness of the ways in which people's sense of self as researchers are affected in negative ways, including the scale of subtle, apparently everyday interpersonal acts. We emphasize the need to recognize the cumulative and harmful nature of these experiences throughout the professional and personal lives of marginalized peoples and the ways in which community values expressed in places like conferences can perpetuate the privileged sense of self enjoyed by already dominant groups.

Warming the climate

Conferences offer insight into where and how women, men, and people of colour are currently participating in the geosciences and how the cultural values and behaviours of the geoscience community might affect this participation. Our study examined a large Canadian geoscience conference in a systematic fashion to compare where women, men, and people of colour presented at the conference, what types of contributions they made, and how presenters and audiences behaved. Our aim has been to explore how conferences act as culturing institutions; for the aspiring geoscientist, their experience of a conference can tell them which types of people and what types of work deserve to be respected and valued.

Compared with registration rates, women were under-represented as oral presenters and invited speakers, as well as over-represented as poster presenters. Although we do not have the registration data to say the same for people of colour, international scholarship suggests people of colour are similarly under-represented in senior roles in science (Ong et al. 2011). Analysis of the presentations at the conference revealed how women and people of colour utilise different methods and make different types of scientific contributions. This information can help to identify significant gaps in access to particular types of research resources (such as labs, instrumentation) and can also suggest how the research community might revalue different types of work (such as applied work or modelling) in ways that highlight the already excellent contributions being made by women and people of colour in these fields. By analysing the behaviour of presenters and audiences, we have explored how a myriad of actions—from timekeeping and in-jokes to aggressive questioning and disrespectful audiences—can work together to contribute to a chilly climate for women and people of colour by creating a sense of belonging for only some types of people.

Although conferences are by no means the only or even the primary site for socializing aspiring geoscientists, they nevertheless provide signals about what scientists should value intellectually, who counts as a role model, how scientists of different identities and subject areas should be treated, and how language should be used to assert one's sense of belonging to the field. They are important places

where cultural norms can be challenged and altered and where positive experiences can be accrued for all attendees. To supplement the important suggestions of previous authors to create more inclusive conference experiences for all attendees (e.g., Sardelis et al. 2017), we conclude our paper with recommendations for action and reflection.

1. The ongoing benchmarking of conference participation and membership in professional societies will help to understand where, how, and why diversity is being achieved across the geosciences (Martin 2014). Studies of the same conference/society across time will help to monitor temporal progress, and comparing between disciplines, countries, and scientific societies (e.g., industry conferences) would help to confirm, reject, or refine the types of relationships observed here.

2. Greater emphasis on the real-world justifications of research may open up the scientific community to recognizing, respecting, and rewarding different styles of intellectual contributions and communication, which may help make more people feel welcome and respected as geoscientists. We observed that real-world justifications of research were most often provided by students and appeared to be more valued in sessions with high female participation. By providing real-world justification for their work, researchers speak beyond their established network of peers. This has the potential to generate interest from researchers outside the "in" group and disrupts cultures of talking only to one's own community.

3. Conference participants in all roles should look for constructive opportunities to question dominant and embedded ways of doing things to open up space for new voices and perspectives. For example, territorial acknowledgements of the Musqueam people (the First Nations community on whose unceded land the conference took place) were only made in the introductions of the keynote and plenary lectures. We suggest that a practice of in-session territorial acknowledgements might bring humility and awareness of scientists' roles in society into the rituals and values of science itself.

4. Disciplinary communities with a homogenous workforce may wish to increase their diversity, but may be wary of tokenism and unsure of what meaningful steps they can take to attract and support new demographics of researchers. Reflecting on their behaviour through conference codes of conduct may stimulate discussion about how community behaviour might be contributing to chilly climates, and may empower researchers to make progress towards diversity by changing their own behaviours (see Sardelis et al. 2017). Our findings demonstrate that behaviours contributing to these climates that may be addressed in a code of conduct include (*i*) timekeeping issues (being on time with presentations and keeping questions concise); (*ii*) language (avoiding the use of gendered, racialized, or insider language); and (or) (*iii*) tone of questions (keeping questions polite and acknowledging appropriate venues outside of the question period for more critical questioning of scientific findings).

If the aim of scientific inquiry is to advance knowledge for the betterment of humankind as a whole, then science itself is best served by being open and inclusive of all kinds of humans. All interested geoscientists, including those who already feel at home in their fields, will benefit from more inclusive and generous valuing of personalities and worldviews. This plurality of perspectives equips us as geoscientists to better serve the needs and values of the societies in which we are embedded.

Acknowledgements

The authors thank Maria Elgueta for her participation in data collection and for her input into the final manuscript. We gratefully acknowledge Aaron Glenn of CSAFM and Brett Eaton, Rich Petrone, and Claire Samson of CGU for their permission and support of this project. We thank Natasha Fox, Gerry Pratt, Juanita Sundberg, and Jess Dempsey for their comments on the template and project design. We appreciate editorial feedback on the manuscript from Stefan Gronsdahl, Juliane Collard, and three anonymous reviewers. We are grateful to Eric Leinberger for preparation of the final figures. This research was supported by funding from the Canadian Natural Sciences and Engineering Research Council (NSERC) Canada Research Chair to Michele Koppes.

Author contributions

LK, LM, MT, and MK conceived and designed the study. LK, LM, MT, SC, KM, DR, and MK performed the experiments/collected the data. LK, LM, MT, SC, KM, DR, and MK analyzed and interpreted the data. MK contributed resources. LK, LM, MT, SC, KM, DR, and MK drafted or revised the manuscript.

Competing interests

The authors have declared that no competing interests exist.

Data accessibility statement

All relevant data are within the paper and in the Supplementary Material.

Supplementary material

The following Supplementary Material is available with the article through the journal website at doi:10.1139/facets-2017-0111.

Supplementary Material 1

References

Alper J. 1993. The pipeline is leaking women all the way along. Science, 260(5106): 409–411. PMID: 17838262 DOI: 10.1126/science.260.5106.409

Ballenger J, Polnick B, and Irby B (Editors). 2017. Women of color in STEM: navigating the workforce. Information Age Publishing, Charlotte, North Carolina.

Bear JB, and Woolley AW. 2011. The role of gender in team collaboration and performance. Interdisciplinary Science Reviews, 36(2): 146–153. DOI: 10.1179/030801811X13013181961473

Begiato J, Campbell L, Gray S, and Land I. 2015. Don't be a conference troll: a guide to asking good questions. The Guardian [online]: Available from theguardian.com/higher-education-network/2015/nov/11/dont-be-a-conference-troll-a-guide-to-asking-good-questions.

Biernat M, and Hawley PH. 2017. Sexualized images in professional contexts: effects on anticipated experiences and perceived climate for women and men. Journal of Applied Social Psychology, 47(10): 568–583. DOI: 10.1111/jasp.12461

Biggs J, Hawley PH, and Biernat M. 2017. The academic conference as a chilly climate for women: effects of gender representation on experiences of sexism, coping responses, and career intentions. Sex Roles, 78(5–6): 394–408. DOI: 10.1007/s11199-017-0800-9

Bracken L, and Mawdsley E. 2004. 'Muddy glee': rounding out the picture of women and physical geography fieldwork. Area, 36(3): 280–286. DOI: 10.1111/j.0004-0894.2004.00225.x

Campbell LM, Corson C, Gray NJ, MacDonald KI, and Brosius JP. 2014. Studying global environmental meetings to understand global environmental governance: collaborative event ethnography at the Tenth Conference of the Parties to the Convention on Biological Diversity. Global Environmental Politics, 14(3): 1–20. DOI: 10.1162/GLEP_e_00236

Carey M, Jackson M, Antonello A, and Rushingd J. 2016. Glaciers, gender, and science. Progress in Human Geography, 40(6): 770–793. DOI: 10.1177/0309132515623368

Chachra D. 2017. To reduce gender biases, acknowledge them. Nature, 548(7668): 373. PMID: 28836614 DOI: 10.1038/548373a

Cheryan S, Plaut VC, Davies PG, and Steele CM. 2009. Ambient belonging: how stereotypical cues impact gender participation in computer science. Journal of Personality and Social Psychology, 97(6): 1045–1060. PMID: 19968418 DOI: 10.1037/a0016239

Cheryan S, Ziegler SA, Montoya AK, and Jiang L. 2017. Why are some STEM fields more gender balanced than others? Psychological Bulletin, 143(1): 1–35. PMID: 27732018 DOI: 10.1037/bul0000052

Clancy KBH, Lee KMN, Rodgers EM, and Richey C. 2017. Double jeopardy in astronomy and planetary science: women of color face greater risks of gendered and racial harassment. Journal of Geophysical Research: Planets, 122: 1610–1623. DOI: 10.1002/2017JE005256

Corson C, Campbell LM, and MacDonald KI. 2014. Capturing the personal in politics: ethnographies of global environmental governance. Global Environmental Politics, 14(3): 21–40. DOI: 10.1162/GLEP_a_00237

Dutt K, Pfaff DL, Bernstein AF, Dillard JS, and Block CJ. 2016. Gender differences in recommendation letters for postdoctoral fellowships in geoscience. Nature Geoscience, 9(11): 805–808. DOI: 10.1038/ngeo2819

Egri CP. 1992. Academic conferences as ceremonials: opportunities for organizational integration and socialization. Journal of Management Education, 16(1): 90–115. DOI: 10.1177/105256299201600107

Ellis J, Fosdick BK, and Rasmussen C. 2016. Women 1.5 times more likely to leave stem pipeline after calculus compared to men: lack of mathematical confidence a potential culprit. PLoS ONE, 11(7): e0157447. PMID: 27410262 DOI: 10.1371/journal.pone.0157447

Etzkowitz H, Fuchs S, Gupta M, Kemelgor C, and Ranga M. 2008. The coming gender revolution in science. *In* The handbook of science and technology studies. *Edited by* EJ Hackett, O Amsterdamska, M Lynch, and J Wajcman. MIT Press, Cambridge, Massachusetts. pp. 403–428.

Falkenheim J, Burke A, Muhlberger P, and Hale K. 2017. Women, minorities, and persons with disabilities in science and engineering. National Science Foundation, Arlington, Virginia [online]: Available from nsf.gov/statistics/wmpd/.

Farr CM, Bombaci SP, Gallo T, Mangan AM, Riedl HL, Stinson LT, et al. 2017. Addressing the gender gap in distinguished speakers at professional ecology conferences. BioScience, 67(5): 464–468. DOI: 10.1093/biosci/bix013

Glass JB. 2015. We are the 20%: updated statistics on female faculty in earth sciences in the U.S. *In* Women in the geosciences: practical, positive practices toward parity. *Edited by* MA Holmes, S OConnell, and K Dutt. John Wiley & Sons, Inc., Toronto, Ontario. pp. 17–22.

Griffith AL. 2010. Persistence of women and minorities in STEM field majors: is it the school that matters? Economics of Education Review, 29(6): 911–922. DOI: 10.1016/j.econedurev.2010.06.010

Guterl F. 2014. Diversity in science: why it is essential for excellence. Scientific American [online]: Available from scientificamerican.com/article/diversity-in-science-why-it-is-essential-for-excellence/.

Hawkesworth M. 2010. Policy discourse as sanctioned ignorance: theorizing the erasure of feminist knowledge. Critical Policy Studies, 3(3–4): 268–289. DOI: 10.1080/19460171003619691

Henderson EF. 2015. Academic conferences: representative and resistant sites for higher education research. Higher Education Research & Development, 34(5): 914–925. DOI: 10.1080/07294360.2015.1011093

Hinsley A, Sutherland WJ, and Johnston A. 2017. Men ask more questions than women at a scientific conference. PLoS ONE, 12(10): e0185534. PMID: 29036191 DOI: 10.1371/journal.pone.0185534

Holmes MA. 2015a. Who receives a geoscience degree? *In* Women in the geosciences: practical, positive practices toward parity. *Edited by* MA Holmes, S OConnell, and K Dutt. John Wiley & Sons, Inc., Toronto, Ontario. pp. 13–16.

Holmes MA. 2015b. A sociological framework to address gender parity. *In* Women in the geosciences: practical, positive practices toward parity. *Edited by* MA Holmes, S OConnell, and K Dutt. John Wiley & Sons, Inc., Toronto, Ontario. pp. 25–30.

Holmes MA, and O'Connell S. 2003. Where are the women geoscience professors? Papers in the Earth and Atmospheric Sciences, 86. 40 p [online]: Available from digitalcommons.unl.edu/geosciencefacpub/86.

Holmes MA, OConnell S, and Dutt K (Editors). 2015a. Women in the geosciences: practical, positive practices toward parity. John Wiley & Sons, Inc., Toronto, Ontario.

Holmes MA, OConnell S, and Dutt K. 2015b. Introduction. *In* Women in the geosciences: practical, positive practices toward parity. *Edited by* MA Holmes, S OConnell, and K Dutt. John Wiley & Sons, Inc., Toronto, Ontario. pp. 1–9.

Huntoon JE, and Lane MJ. 2007. Diversity in the geosciences and successful strategies for increasing diversity. Journal of Geoscience Education, 55(6): 447–457. DOI: 10.5408/1089-9995-55.6.447

Jarreau PB. 2016. Being female in science. From the Lab Bench [online]: Available from: fromthelabbench.com/from-the-lab-bench-science-blog/2016/3/8/being-woman.

Katila S, and Meriläinen S. 1999. A serious researcher or just another nice girl?: doing gender in a male-dominated scientific community. Gender, Work & Organization, 6(3): 163–173. DOI: 10.1111/1468-0432.00079

Kerkhoven AH, Russo P, Land-Zandstra AM, Saxena A, and Rodenburg FJ. 2016. Gender stereotypes in science education resources: a visual content analysis. PLoS ONE, 11(11): e0165037. PMID: 27851759 DOI: 10.1371/journal.pone.0165037

Leinen M. 2016. Laying a foundation for diversity in earth and space sciences. AGU Blogosphere: From the Prow [online]: Available from fromtheprow.agu.org/foundation-for-diversity-in-earth-and-space-sciences/.

Lerback J, and Hanson B. 2017. Journals invite too few women to referee. Nature, 541(7638): 455–457. PMID: 28128272 DOI: 10.1038/541455a

Levine R, González R, Cole S, Fuhrman M, and Le Floch KC. 2007. The geoscience pipeline: a conceptual framework. Journal of Geoscience Education, 55(6): 458–468. DOI: 10.5408/1089-9995-55.6.458

Luzzadder-Beach S, and Macfarlane A. 2000. The environment of gender and science: status and perspectives of women and men in physical geography. The Professional Geographer, 52(3): 407–424. DOI: 10.1111/0033-0124.00235

Martin JL. 2014. Ten simple rules to achieve conference speaker gender balance. PLoS Computational Biology, 10(11): e1003903. PMID: 25411977 DOI: 10.1371/journal.pcbi.1003903

Moss-Racusin CA, Dovidio JF, Brescoll VL, Graham MJ, and Handelsman J. 2012. Science faculty's subtle gender biases favor male students. Proceedings of the National Academy of Sciences of the USA, 109(41): 16474–16479. PMID: 22988126 DOI: 10.1073/pnas.1211286109

Nelson A. 2017. Commentary: diversity in physics: are you part of the problem? Physics Today, 70(5): 10–11. DOI: 10.1063/PT.3.3536

Nentwich FW. 2010. Issues in Canadian geoscience—women in the geosciences in Canada and the United States: a comparative study. Geoscience Canada, 37(3): 127–134.

Nielsen WM, Alegria S, Börjeson L, Etzkowitz HJ, Falk-Krzesinski HJ, Joshi A, et al. 2017. Opinion: gender diversity leads to better science. Proceedings of the National Academy of Sciences of the USA, 114(8): 1740–1742. PMID: 28228604 DOI: 10.1073/pnas.1700616114

NSERC. 2010. Women in science and engineering in Canada. Natural Sciences and Engineering Research Council, Ottawa, Ontario.

NSF. 2001. Strategy for developing a program for opportunities for enhancing diversity in the geosciences. National Science Foundation, Washington, D.C. [online]: Available from nsf.gov/geo/diversity/geo_diversity_strategy_document_jan_01.jsp.

NSF. 2011. Science and engineering degrees: 1966–2008. National Center for Science and Engineering Statistics, National Science Foundation, Arlington, Virginia.

Ong M, Wright C, Espinosa L, and Orfield G. 2011. Inside the double bind: a synthesis of empirical research on undergraduate and graduate women of color in science, technology, engineering, and mathematics. Harvard Educational Review, 81(2): 172–209. DOI: 10.17763/haer.81.2.t022245n7x4752v2

Ratliff JM. 2012. A chilly conference climate: the influence of sexist conference climate perceptions on women's academic career intentions. Ph.D. thesis, University of Kansas, Lawrence, Kansas. 110 p.

Rosen J. 2017. Data illuminate a mountain of molehills facing women scientists. Eos, 98 [online]: Available from eos.org/features/data-illuminate-mountain-molehills-facing-women-scientists.

Sardelis S, and Drew JA. 2016. Not "pulling up the ladder": women who organize conference symposia provide greater opportunities for women to speak at conservation conferences. PLoS ONE, 11(7): e0160015. PMID: 27467580 DOI: 10.1371/journal.pone.0160015

Sardelis S, Oester S, and Liboiron M. 2017. Ten strategies to reduce gender inequality at scientific conferences. Frontiers in Marine Science, 4: 1–6. DOI: 10.3389/fmars.2017.00231

Schroeder J, Dugdale HL, Radersma R, Hinsch M, Buehler DM, Saul J, et al. 2013. Fewer invited talks by women in evolutionary biology symposia. Journal of Evolutionary Biology, 26(9): 2063–2069. PMID: 23786459 DOI: 10.1111/jeb.12198

Settles IH, and O'Connor RC. 2014. Incivility at academic conferences: gender differences and the mediating role of climate. Sex Roles, 71(1–2): 71–82. DOI: 10.1007/s11199-014-0355-y

Shen H. 2013. Inequality quantified: mind the gender gap. Nature, 495: 22–24. PMID: 23467149 DOI: 10.1038/495022a

Skibba R. 2016. Women in physics face big hurdles—still. Nature News [online]: Available from nature.com/news/women-in-physics-face-big-hurdles-still-1.20349.

Statistics Canada. 2011. 2011 National Household Survey: data tables. Catalogue no. 99-012-X2011033. Statistics Canada, Ottawa, Ontario.

Thornbush M. 2016. Introduction to the special issue on gender and geoethics in the geosciences. International Journal of Environmental Research and Public Health, 13(4): 398. PMID: 27043609 DOI: 10.3390/ijerph13040398

Topaz CM, and Sen S. 2016. Gender representation on journal editorial boards in the mathematical sciences. PLoS ONE, 11(8): e0161357. PMID: 27536970 DOI: 10.1371/journal.pone.0161357

Urry M. 2015. Science and gender: scientists must work harder on equality. Nature, 528: 471–473. PMID: 26701038 DOI: 10.1038/528471a

Williams JC, Phillips KW, and Hall EV. 2014. Double jeopardy? Gender bias against women of color in science. The Center for WorkLife Law, San Francisco, California [online]: Available from worklifelaw.org/publication/double-jeopardy-gender-bias-against-women-of-color-in-science/.

Wilson CE. 2017. Representation of women in the geoscience workforce in 2013. Geoscience Currents No. 120. American Geoscience Institute, Alexandria, Virginia [online]: Available from: americangeosciences.org/sites/default/files/currents/Currents-120-WomenGeoscientists2013.pdf.