

**Council of Chairs of Canadian Earth Science Departments
CCCESD Meeting, online, 12 November 2020**

AGENDA – all times in Eastern Standard Time

11:00 – 11:10 Introduction and welcome (Russ Pysklywec - Chair)

11:10 – 11:15 CCCESD Finances (submitted by John Greenough)

11:15 – 11:20 CCCESD statistics (Rob Raeside) – attachments, p. 1

11:20 – 11:30 Report from CFES (Sam Butler) – attachments, p. 8-15

11:30 – 12:00 Interactions between Canadian Earth Science departments and geoscience professional regulators (Craig Nichol) – attachments p. 2-3

12:00 – 12:30 Geoscientists Canada

Andrea Waldie, CEO; Kevin Ansdell, President-Elect

12:30 – 1.00 Issues arising

Open time to develop points for discussion with NSERC, CFI

1:00 – 2.00 NSERC Session

Dave Bowen, interim Team Leader, Mathematical, Environmental and Physical Sciences

Tiffany Lancaster, Program Officer

Kenn Rankine, Program Officer

2.00 – 2.30 Break

2.30 – 3.00 Canada Foundation for Innovation presentation

Claire Samson, Vice-President

Mohamad Nasser-Eddine, Director

3.00 – 3.30 News from the Geological Survey of Canada

Daniel Lebel, Director General, GSC

Geneviève Marquis, Director of GSC Central Canada

Linda Richard, Geomapping for Energy and Minerals

Katherine Mitchell

Celina Campbell

3.30 – 5.00 Open for round-table discussions

Covid-19 issues

EDI issues (see attachments, p. 4-7)

5.00 – 5:30 Executive changes

List of members in CCCESD

Memorial University	Western University
Greg Dunning	Patricia Corcoran
Penny Morrill, Deputy Head	Windsor
Christine Campbell, Corner Brook	Joel Gagnon
Cape Breton University	Laurentian University
Deanne van Rooyen	Doug Tinkham
St. Francis Xavier University	Lakehead University
Lisa Kellman, chair	Pete Hollings
St. Mary's University	Manitoba
Pierre Jutras	Alfredo Camacho
Dalhousie University	Brandon University
James Brenan	Hamid Mumin
Acadia University	Regina
Rob Raeside	Kathryn Bethune
UNB Saint John	Saskatchewan
Lucy Wilson	Sam Butler (on leave)
UNB Fredericton	Bruce Eglington
Karl Butler	Mt. Royal University
Université du Québec à Chicoutimi	Gwen O'Sullivan, chair
Réal Daigneault	Jeff Pollock
Université Laval	Calgary
Marc Constantin	Stephen Hubbard
McGill University	Alberta
Jeff McKenzie	Stephen Johnston
Université du Québec à Montréal	UBC Okanagan
Alain Tremblay	Ed Hornibrook
Ottawa University	Thompson Rivers University
David Schneider	Nancy Van Wagoner
Carleton University	Simon Fraser University
Brian Cousens	Glyn Williams-Jones
Queen's University	UBC Vancouver
Vicki Remenda	Philippe Tortell
York University	Victoria
JinJun Shan	Stan Dosso
Toronto	Vancouver Island University
Russ Pysklywec	Jerome Lesemann
Toronto at Mississauga	Tim Stokes
Jochen Halfar	Yukon University
Brock University	Joel Cubley
Frank Fueten	
Francine McCarthy	CCCESD treasurer
McMaster University	John Greenough, UBC-O
Bruce Newbold	
Waterloo	
Dave Rudolph	

SUMMARY OF UNIVERSITY ENROLMENTS AND STAFFING IN EARTH SCIENCE DEPARTMENTS IN CANADIAN UNIVERSITIES, TO DECEMBER 2019

Compiled by Rob Raeside, Acadia University, and Alan Beck, UWO

Response rate*: 30/38

Fig. 1. Number of BSc (> year 1), MSc and PhD program registrants

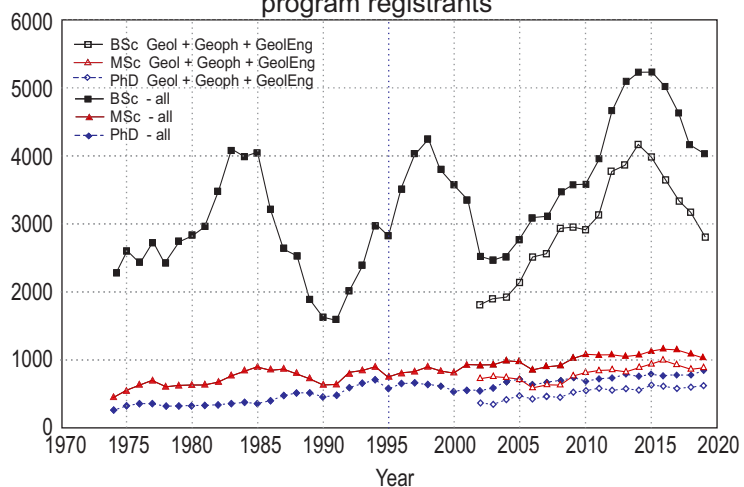


Fig 2. Registrants in service and pre-year 2 courses

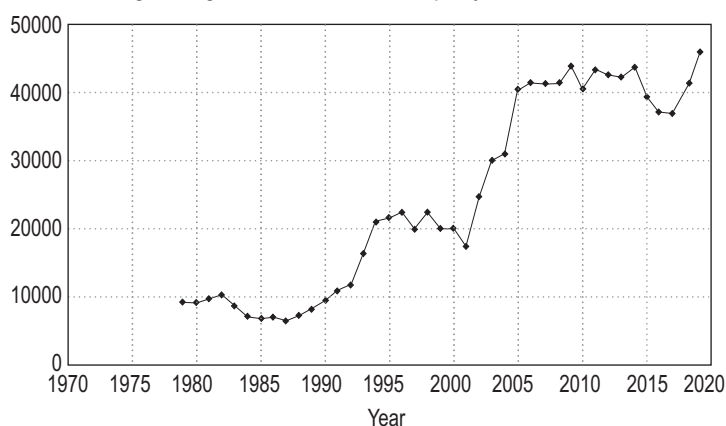


Fig. 3. Numbers of graduated students

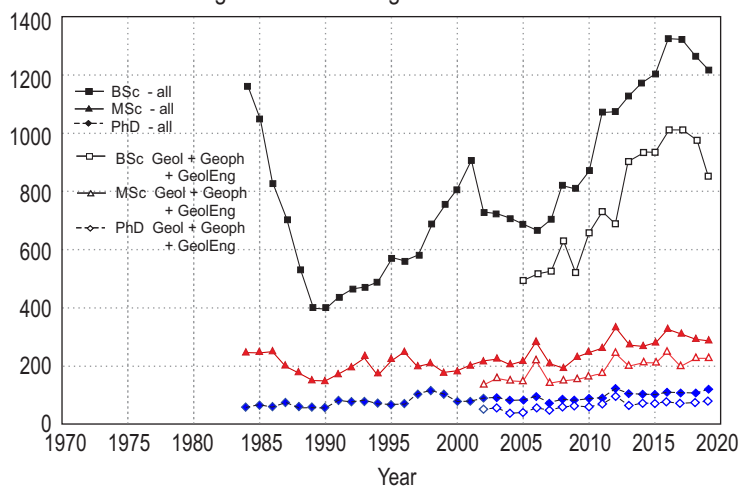


Fig 4. Percentage of females in each of undergraduate, masters, doctoral, and faculty levels

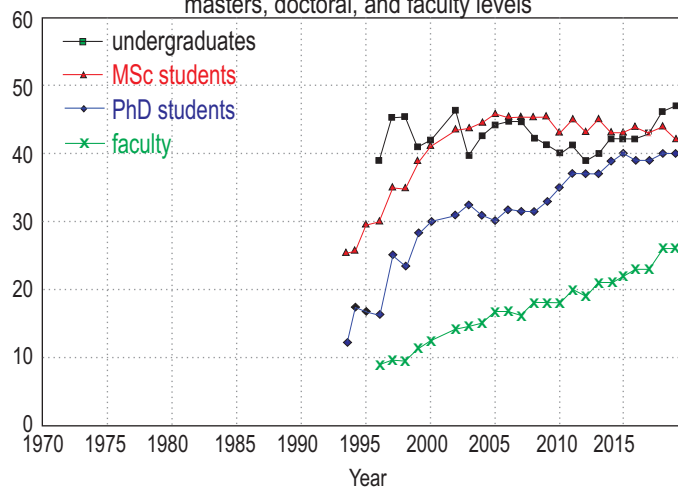


Fig. 5. Numbers of faculty, post-docs and support staff

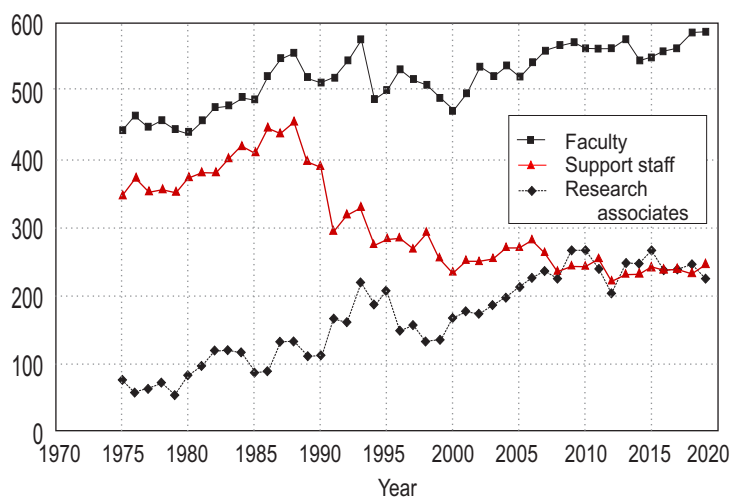
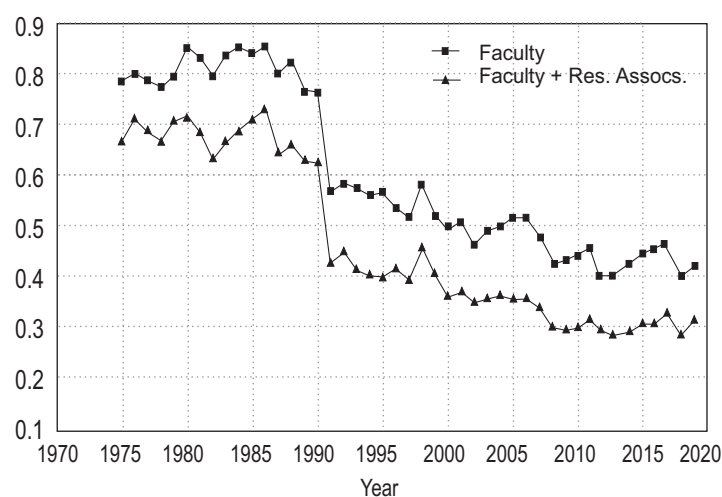


Fig. 6. Ratio of support staff to faculty and post-docs



*30 out of 38 universities have responded to date this year - for those departments not responding, last year's data were used. Non-responding departments represent approximately 23% of all undergraduate enrolments.

Proposed inquiry for consideration by the CCCESD:

How can Canadian Earth Science departments best manage their interactions with the regulators of professional geoscience in order to have the most productive relationships?

Proponent: Craig Nichol, PhD, PGeo
Associate Head of Department
Earth, Environmental and Geographic Sciences
University of British Columbia

Study Overview

Earth Science departments have transitioned from a more traditional geoscience core to become interdisciplinary, multidisciplinary and transdisciplinary. Modern programs are typically wider in scope than the disciplinary bounds of the geology, geophysics and environmental geoscience regulators who oversee applied practitioners. Geoscience regulators are the primary relationship departments have with the professions, with agrology and environmental science typically being secondary options. The implementation of professional geoscience regulation in Canada resulted in a mixed response from geoscience practitioners and from academic Earth Science departments. Currently, the professional regulators and academic departments have varied relationships.

Geoscience graduates are encountering increased requirements for registered professional status as provinces have moved to professional reliance models, and are engaging in greater oversight of professions. The next 5 to 10 years will likely see increased provincial- and national-level discussions regarding areas of practice, particularly between geoscience, agrology and environmental science. In British Columbia for example, the government has introduced new legislation to bring the natural resource related professions (agrology, biology, engineering, forestry, and geoscience) under a common regulatory framework through the new BC Professional Governance Act. These professions all will acquire rights of practice, something which currently applies only to geoscience and engineering. Discussions are under way in the agrology and environmental sciences communities regarding provincial regulation and national practice standards. There is also increased interest in competency-based assessment at entry to practice and potential for discussion of content-based degree syllabi transitioning to inclusion of graduate attributes or other competency-based assessment. These changes suggest academic departments should strive to establish good relationships with regulators in order to be influential and up to date. It is in the best interest of all stakeholders – the Earth Science departments, the regulators, the geoscientists, and even the public – for the Earth Science departments and the regulators to have strong relationships.

It is unclear the extent to which Canadian Earth Science departments are prepared to be stakeholders in national discussions about professional practice and regulation. This inquiry will focus on how to best structure management of the relationship between departments and professional regulatory bodies. It will collect quantitative data and access historical CCCESD data about basic departmental-professional alignment. Departments will be asked to complete a short survey and to provide contact information for individuals who manage degree program relations with professional regulators. The inquiry will engage with departmental representatives to determine what strategic approaches departments can use to improve or strengthen relationships with regulators. It will examine contextual factors, current best practices and what key institutional or national supports would help to support departments. The study will be presented in late 2021 to the CCCESD, to Geoscientists Canada and other geoscience regulators, and

to regulators of other professions in the natural sciences. Provincial regulators will be approached about whether to undertake a parallel study.

The CCCESD can support this study by granting access to past historical data for departments. Department heads can support the initiative by completing the short departmental survey and by recognizing and encouraging efforts of departmental members who participate in the study. It is expected that the study will ask each department to spend a short time discussing the matter at a departmental meeting in the spring of 2021.

No progress on diversity in 40 years

Ethnic and racial diversity are extremely low among United States citizens and permanent residents who earned doctorates in earth, atmospheric and ocean sciences. Worse, there has been little to no improvement over the past four decades.

Rachel E. Bernard and Emily H. G. Cooperdock

The geosciences tackle the complexities of the Earth. Geoscientists also study how we, as a society, affect — and are affected by — the planet we live on. Complex problems that influence all segments of society, such as demands on diminishing natural resources and climate change, require the ingenuity of investigators with a broad variety of backgrounds. Increased diversity has clear benefits for scientific advancement: different perspectives and life experiences spark unique questions and approaches to problem solving¹. Collaborations involving a diverse group of people are more creative at tackling problems and lead to higher levels of scientific innovation². Nevertheless, the geosciences are the least diverse of all STEM (science, technology, engineering and mathematics) fields.

We noticed the lack of ethnic and racial diversity among our peers as soon as we entered our PhD programme. The uniformity worsens from undergraduate to graduate to faculty level. The data support this perception; years of outreach have

yet to make any significant strides toward increasing diversity at the PhD level. Efforts to increase diversity have primarily been focused on feeding the pipeline in schools and at the undergraduate level. Yet, at all degree levels, the geosciences remain the least diverse discipline within STEM³.

If we want to broaden the ethnic and racial range of people in the geoscience faculty, we first need PhD graduates who can fill the positions. We highlight the persistence of the geoscience doctorate diversity problem in the United States (US), on the basis of more than 40 years of publicly available demographic data for doctorates in the earth, ocean and atmospheric sciences earned by US citizens or permanent residents (Box 1)⁴. Whereas significant gains have been made in terms of gender balance among PhD recipients in the geosciences, there are few signs of improvement on the ethnic and racial diversity front at the doctorate level. In light of this failure to broaden the base of PhD-level researchers, the community

needs to rethink current strategies aimed at diversifying our academic departments.

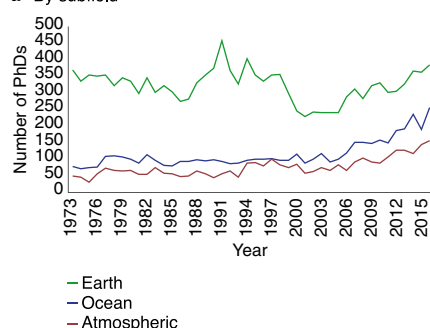
Race and ethnicity over time

The number of PhDs awarded in the earth sciences to US citizens and permanent residents has been relatively stable — around 350 per year since 1973 (Fig. 1a) — whereas the number of ocean and atmospheric science PhDs have risen remarkably in the latest decade. Taking all three disciplines together, about 60% more PhDs were awarded in 2016, compared to 1973.

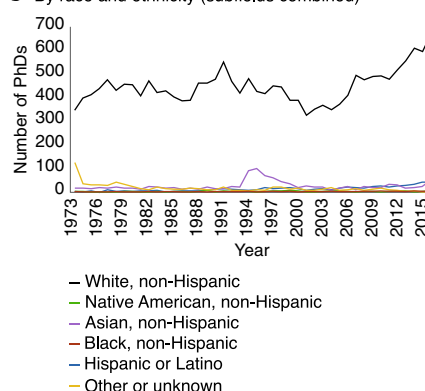
When we combine all three subdisciplines — ocean, atmosphere and earth sciences (Box 1) — and stratify by self-reported ethnicity, it becomes clear that the vast majority of PhDs (86% over all years and 85% in 2016 alone) were awarded to students who identify as non-Hispanic White people (Fig. 1b; Table 1). Even more depressingly, over the 40 years covered by our data, the representation of students from underrepresented minorities (American Indian or Alaska Native, Black or African American, and Hispanic or Latino groups)⁴

Total PhDs earned over time

a By subfield



b By race and ethnicity (subfields combined)



c For underrepresented minorities only (subfields combined)

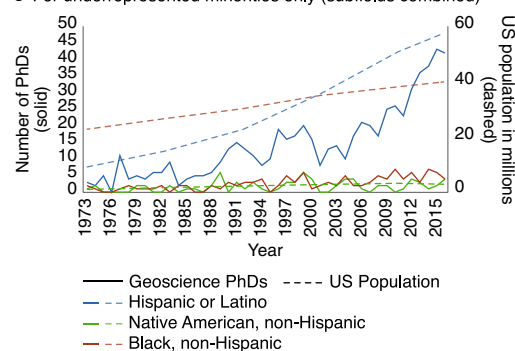


Fig. 1 | PhDs earned by US citizens and permanent residents between 1973 and 2016. **a**, The total number of PhDs for all races, ethnicities and genders combined have fluctuated around 350 for the earth sciences, but have taken an upward turn from a stable base level in the last decade or so for ocean and atmospheric sciences. **b**, The largest race/ethnicity category by far is the White non-Hispanic PhD group. **c**, Focusing on what the NSF considers to be underrepresented minorities (that is, excluding White non-Hispanics and Asian non-Hispanics), and comparing with the increasing share of these groups in the US population (measured by decadal census and 2016 estimate), it becomes clear that gains in Hispanic or Latino PhDs largely reflect an increase in the relevant population in the US, and that there are no gains in PhDs earned among the other underrepresented groups. Data in **a–c** run from 1973 to 2016.

Box 1 | The data

The basis for our assessment is the Survey of Earned Doctorates (SED), an annual census, sponsored by several federal agencies, of individuals who receive research doctoral degrees from accredited US academic institutions⁴. The findings are reported through the NSF's National Center for Science and Engineering Statistics. The data come from survey forms distributed by graduate coordinators at doctorate-awarding institutions or direct e-mails to recent graduates. Response rates in recent years have been about 90%. For our purposes, we chose to look at the SED demographic data for US citizens and permanent residents since 1973, the year SED began collecting race and ethnicity data.

SED data were mined from multiple sources in order to have as complete a record as possible (see Supplementary Information).

Subfield categories. We collected data from the following specific subfields of the SED dataset: (1) Atmospheric Science and Meteorology; (2) Geological and Earth Sciences; and (3) Ocean/Marine Sciences (all fall within the broader category of 'Physical Sciences'). For clarity and simplicity, we refer to the three subfields as 'atmospheric', 'earth', and 'ocean' sciences, and refer to the three collectively as 'the geosciences'.

Doctorate recipients filling out the SED are provided with a list of several academic subjects and are prompted to self-select which subject best describes

their area of research (for example, Chemical and Physical Oceanography is a subject within the Ocean/Marine Sciences subfield). For a complete list of subjects provided in the SED survey form for the three subfields, see Supplementary Information.

Racial and ethnicity categories. The SED divides US citizens and permanent residents into (a) Hispanic or Latino; and the following 'Not Hispanic or Latino' racial categories: (b) American Indian or Alaska Native; (c) Asian; (d) Black or African American; (e) White; (f) more than one race; and (g) other or race unknown. Doctorate recipients who report Hispanic or Latino ethnicity, regardless of racial designation, are counted as Hispanic or Latino. Therefore, there may be people who consider themselves White, for example, who are counted only in the Hispanic or Latino category. For changes in these categories over time, see Supplementary Information.

We refer to underrepresented minorities as groups that are underrepresented in science and engineering, relative to their numbers in the US population (as defined by NSF)⁴. These groups include American Indian or Alaska Native (referred to as 'Native American'), Black or African American (referred to as 'Black'), and Hispanic or Latino groups.

Gender categories. SED gender categories are self-reported, and limited to male and female.

the result of a change in the categorization.

We are alarmed that the proportion of underrepresented minorities among PhD recipients in the geosciences has not improved in any meaningful metric over more than four decades, despite the efforts by our community to try to increase diversity, particularly in the past 20 years following the development of the National Science Foundation (NSF)'s Broader Impacts initiative⁵.

Gender over time

Predictably, in 1973, men vastly outnumbered women (Fig. 2, Table 1). However, the percentage of women earning PhDs has steadily climbed in all subfields; and in the ocean sciences, the number of women has even surpassed the number of men earning PhDs since 2009 (Fig. 2c). Women briefly outnumbered men in the earth sciences for one year (Fig. 2a).

In the earth sciences, where the total number of PhDs awarded has remained relatively constant over the past 40 years (Fig. 1a), the absolute number of doctorates going to men has actually decreased substantially over time from 347 male recipients of PhDs in 1973, to 212 in 2016. This trend holds only for White male students; for men of other ethnicities or races, no similar trend is observed. This is not at all unique to the earth sciences. For example, data from the Survey of Earned Doctorates⁴ (SED) show that over the same period, the number of doctorates going to White men in economics, psychology and physics has decreased by 50%.

The bigger picture

In 2016, only 6% of geoscience doctorates awarded to US citizens and permanent residents went to students from underrepresented minorities, a group who made up 31% of the US population that year⁶ (Table 1). With this number, the geosciences have the lowest proportion of

has essentially been stagnant when compared with the proportion of the relevant groups in the US population (Fig. 1c).

The very low number of 'other race or unknown' students (Fig. 1b) suggests

that the race and ethnicity questions were rarely skipped; the spike in Asian PhD recipients in the mid-to-late 1990s also appears in other fields, such as chemistry and economics, and is thus probably

Fig. 2 | Gender balance. a–c, According to the SED data from 1973–2016, the gender gap has narrowed considerably in the earth sciences (a), and somewhat less in the atmospheric sciences (b). In the ocean sciences, more women than men have earned PhDs since 2009 (c). Refer to Box 1 for information on subfield categories. Data in a–c run from 1973 to 2016.

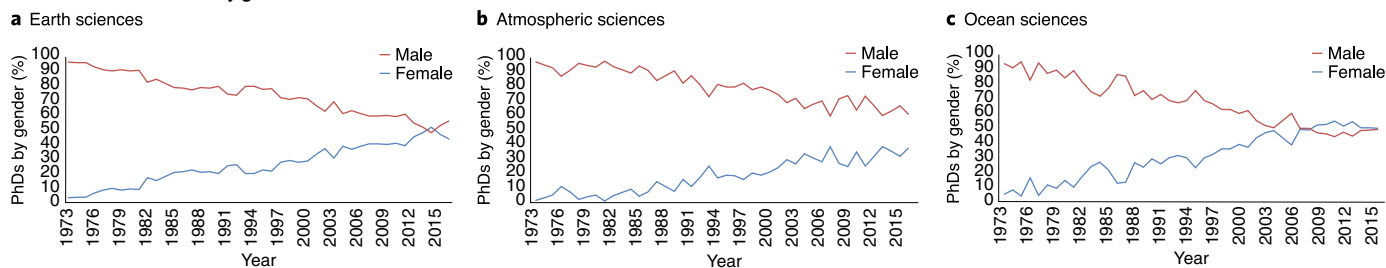


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Table 1 | Total number of doctorates awarded from 1973 to 2016, along with calculated percentages of race, ethnicity and gender for the most recent year in the dataset

R&E	Earth		Ocean		Atmospheric		All geosciences		2016 comparative percentages	
	Cumulative number	Per cent in 2016	Cumulative number	Per cent in 2016	Cumulative number	Per cent in 2016	Cumulative number	Per cent in 2016	All S&E PhDs ^c	US population ^d
White	12,279	86	4,435	87	2,856	75	19,570	85	73	61
Asian	622	5	237	6	324	11	1,183	6	10	6
Hispanic or Latino	335	4	198	4	95	9	628	5	7	18
Black	115	1	58	0	59	4	232	1	6	12
Native American	52	1	15	0	7	1	74	1	<1	1
Other or unknown	523	<1	145	<1	95	0	763	<1	1	<1
Two or more races ^a	92	3	50	3	22	1	164	3	3	2
Total	14,018	100	5,138	100	3,458	100	22,614	100	100	100
Per cent URM ^b		6		4		13		6	13	31
Gender	Per cent over all years	Per cent in 2016	Per cent over all years	Per cent in 2016	Per cent over all years	Per cent in 2016	Per cent over all years	Per cent in 2016	All S&E PhDs ^c	US population ^d
Per cent male (all R&Es)	74	56	65	50	78	62	73	55	53	49
Per cent female (all R&Es)	26	44	35	50	22	38	27	45	47	51

^aOnly recorded since 2001. ^bURM totals only include Hispanic or Latino, Black and Native American individuals. ^cSource: National Science Foundation, National Center for Science and Engineering Statistics⁴.

^dSource: Kaiser Family Foundation⁵. R&E, race and ethnicity; S&E, science and engineering; URM, underrepresented minority.

doctorate recipients from underrepresented minorities among all STEM fields: in the physical sciences, the broad field which includes the geosciences, the percentage of doctorates awarded to students from underrepresented minorities amounted to 8% (regarding other broad fields, the numbers were 11% for mathematics and computer science, 11% for engineering, 14% for life sciences and 17% for psychology and social science). Averaged over all science and engineering students, 13% of doctorates went to underrepresented minorities — more than twice the percentage achieved in the geosciences, and still a very long way from an adequate representation of these groups compared to their proportion of the population⁶ (Table 1).

At 6% in 2016, the percentage of Asian Americans earning doctorates in the geosciences was roughly in line with their proportion in the US population; this group is therefore not considered to be underrepresented in STEM subjects by the NSF.

The change in gender balance is a bright spot in the data, although the field as a whole, and the atmospheric sciences in particular (Fig. 2b), still has room for improvement. However, between 2006 and 2016, female geoscience faculty representation has increased from 14% to 20%, so some progress is being made⁷.

When and how these upward trends in female representation will translate into true gender balance at the faculty level remains to be seen.

By contrast, ethnic and racial diversity within the geosciences has stagnated, even at the doctorate level. Hispanics and Latinos are the only underrepresented group that shows improved representation; however, this increase (223% since 1990) is largely explained by the fact that this group has grown dramatically in size (157% since 1990) within the US population (Fig. 1c)⁸. Clearly, we still have a long way to go if our goal is to have a geoscience doctorate community that is representative of our wider population.

Unsurprisingly, women of colour are particularly underrepresented. Between 1973 and 2016, the numbers are bleak: only 20 Native American, 69 Black and 241 Hispanic or Latino women received PhDs in all three geoscience subdisciplines combined. They make up a mere 330, or 1.46%, of all doctorates awarded in over 40 years.

Where to from here

Many of us have been acutely aware of the lack of ethnic and racial diversity every time we walk into our departments, or into large international conferences such as the meetings of the American Geophysical Union or the Geological Society of America.

There, we see very few people that look like us. Indeed, as recently as 2012, scientists from underrepresented minorities made up only 3.8% of tenured or tenure track faculty⁹ in the top 100 earth science departments.


The observation that there has been little or no progress over the past 40 years implies that the efforts from the 1990s onwards to increase diversity at the grade school and undergraduate levels have not translated into diversity at the PhD, let alone faculty, level. Certainly, these outreach efforts are worthwhile and have probably reached hundreds to thousands of students, but they are clearly nowhere near sufficient to shift our demographics. It is entirely possible that on their own, they will never translate into diversity at the doctorate level, which is necessary to ultimately diversify at the faculty level.

As a community, we need to think deeply and seriously about why the underrepresentation of some groups is so persistent, and what initiatives we can develop to make sure students from all backgrounds feel welcomed, excited, empowered and capable of succeeding at higher education in the geosciences. Initiatives aimed at grade school and undergraduate students address some of the underlying reasons why the geosciences may be less attractive to underrepresented groups, such as lack of exposure to the natural environment, field requirements and perceptions of job prospects.

We can think of a few actions that could specifically make geoscience doctorates more appealing to these groups. Much can be done on the department or university level, such as establishing more diversity fellowships to attract and retain graduate students. We can also take lessons from the success of other physical science disciplines that use the master's degree as a pathway to PhD, such as transition programmes that partner minority-serving institutions with research universities through collaborative research¹⁰.

We also should think about how the current model of graduate school might not serve the specific personal interests or motivations of people from underrepresented groups. For example, research in other STEM fields finds that doctoral students of colour are more likely to be motivated by altruistic values and a desire to give back to their communities than their majority peers^{11–13}. Perhaps encouraging or even rewarding graduate students who want to devote time to community outreach and engagement — either as a course or dissertation requirement, or as a fellowship, similar to the now-retired but successful NSF GK-12 programme¹⁴ — would go a long way to make our field relevant to more people.

Additionally, key geoscience organizations should provide specific funding for minority undergraduate and graduate students to attend their conferences, and departments and universities should provide funding for their students and faculty (regardless of race) to attend national minority-serving conferences. Increased presence at conferences such as the Society for Advancement of Chicanos/Hispanics and Native Americans in Science and the National Association of Black Geoscientists would not only serve to recruit a greater diversity of students, but promote careers and opportunities in the geosciences.

As a geoscience community, we cannot afford to miss out on the extraordinary talent that exists within currently underrepresented minority groups. We will limit the science we do if we do not become more inclusive. We need to do better. 

**Rachel E. Bernard^{1*} and
Emily H. G. Cooperdock^{2*}**

¹*Department of Geological Sciences, University of Texas at Austin, Jackson School of Geosciences, Austin, TX, USA.* ²*Woods Hole Oceanographic Institution, Woods Hole, MA, USA.*

*e-mail: rachelbernard@utexas.edu;
ecooperdock@whoi.edu

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Additional information

Supplementary information is available for this paper at <https://doi.org/10.1038/s41561-018-0116-6>.

1 Introduction

2 Climate change has evolved from scientific curiosity to being part of our daily lives through
3 extreme weather events, media interest, and as a priority for our political leadership at all
4 levels. Northern Canada has experienced some of the most rapid climate warming on Earth,
5 with, for example, mean annual temperatures at Inuvik, NT, climbing from -9.7 °C in 1960-69 to
6 -6.0 °C in 2010-19. Indigenous people and northern residents confirm that these changes have
7 been occurring steadily since the 1970s. The rates of change in the south are lower, but just as
8 definitive. For example, at Ottawa, ON, the mean annual temperatures for 1960-69 and 2010-
9 19 were 6.1 and 7.2 °C, respectively.

10 The Canadian Federation of Earth Sciences has published this statement on climate
11 change to present its fundamental understanding of the issue and to highlight the critical role
12 of the earth sciences in mitigation of climate change and management of its effects in Canada.
13 (155 words)

14
15 Suggested illustrations: Record of annual temperatures at Inuvik; map of Canada to show
16 regional warming.
17

18 Understanding the science of climate change

19 The geological record shows us that global climate has changed throughout Earth's history, but
20 the current and anticipated *rates* of change are unprecedented. Climate change is caused by
21 four fundamental factors: (1) changes in the energy Earth receives from the Sun; (2) changes in
22 the circulation of the atmosphere and the oceans; (3) changes at the surface of the Earth that
23 affect how solar energy is absorbed or redistributed; and (4) changes in the composition of the
24 atmosphere wrought by geological and ecological processes and human activity. Over the last
25 50 years, the greatest adjustment to these factors has been in the composition of the
26 atmosphere, particularly in terms of the concentration of energetically important gases,
27 including carbon dioxide (CO₂), methane (CH₄), and water vapour (H₂O). Each gas traps energy
28 re-emitted from the Earth's surface in the atmosphere and warms our planet. This leads to a
29 more vigorous circulation in the atmosphere and oceans moving heat towards the cooler polar
30 regions.

31 For nearly 200 years we have known about the climatic impact of the atmospheric
32 greenhouse effect, without which our planet would be about 30 °C cooler. The atmosphere's
33 role as a radiation blanket was first proposed by the French scientist Joseph Fourier in 1824.
34 The radiative properties of CO₂ were discovered by the Irish scientist John Tyndall in 1859, so
35 for more than 160 years we have known that CO₂ is one of the principal agents responsible for
36 such warming. Now we simulate the climate using vast and detailed computer models, tested
37 against decades of weather observations. The global scale of the models means that they
38 portray the atmosphere slightly differently, and so do not precisely mirror each other, but all
39 clearly point to warming of climate and shifting distribution of precipitation as the greenhouse
40 effect is enhanced by human activity. (302 words)

Suggested illustrations: Diagram of the greenhouse effect, with radiation fluxes; photograph of John Tyndall.

Validation of the greenhouse effect by the geological record

The deep history of Earth's climate is best preserved in the beds of sediments laid down at the bottom of our lakes and oceans, the annual bands of ice formed from compressed snow in glaciers and ice caps, and in growth rings of trees that document more recent conditions. These give precise records of global climate change over the past thousand years up to scales of millions of years. For example, ocean sediments have presented a record of successive glaciations in the last 2.6 million years, notably through variation in the chemical composition of marine shells buried in these sedimentary sequences. Ice caps have revealed a similar record, created through examination of the chemistry, or isotopes, of oxygen in the H₂O molecules of the ice. The records from ice in Antarctica go back over 700,000 years. Atmospheric gases sealed in the ice layers were trapped as the snow fell and was subsequently compressed. The gas bubbles record the composition of the atmosphere when the ice formed. Analysis of these ancient atmospheric samples shows the CO₂ concentration varying in step with the climate. Similar data describe the initiation of the southern polar ice sheet under a cooler climate following appearance of the first extensive forests in the geological record, 420 to 300 million years ago during the Devonian and Carboniferous Periods. (220 words)

Suggested illustrations: climate record from ocean sediments; Antarctic ice core coincidence of CO₂ concentrations and climate.

Fossil fuels and climate

CO₂ and other gases are important by-products from the extraction, transportation, and combustion of coal, petroleum oil, and natural gas. These energy sources were themselves created by the burial and decomposition of plants (coal) and of micro-organisms and plants (oil and gas) over time since the Paleoproterozoic, at least 1600 million years ago. Subsequently, the organic matter has been modified by heat and pressure during interment beneath younger sediments, especially in the Carboniferous, removing vast quantities of carbon from the atmospheric system and cooling the Earth. The return of this carbon to the atmosphere through the burning of oil, gas and coal in the past 200 years has reversed the effect, increasing CO₂ concentration in the atmosphere and greenhouse warming. Before the Industrial Revolution, the concentration was about 280 parts per million (ppm) but it is now over 410 ppm. It has risen exponentially over the period of continuous measurement since 1958 from about 315 ppm to its present value (<https://www.co2.earth/daily-co2>) and is now at its highest level of at least the last 4 million years. The concentration has been much higher in the deep past, particularly 400 and 200 million years ago, leading to very different worlds at those times than that we now inhabit. The increase in the present concentration of CO₂ and other gases globally

is due *primarily* to the use of fossil fuels ($\approx 80\%$), and deforestation and burning of forests ($\approx 10\%$). A third amount also accrues from cement manufacturing ($\approx 8\%$). CO_2 and other gases released from these activities remain well mixed in the atmosphere for decades. They are being released at a rate that is too great for all emissions to be taken up by vegetation or mixed into the oceans, hence the increase and sustained accumulation in the atmosphere will continue over the long term. The coincidence of climate change with production and consumption of fossil fuels has been predicted and verified by simulations of Earth's climate throughout the last 40 years. Our national attention is often drawn to the anticipated consequences from climate change as global emissions continue to rise and "extreme" weather events appear to become commonplace. (354 words)

Suggested illustrations: Mauna Loa CO_2 measurements, 1958-2020; Sources of emissions, historical curves .

Amplification of climate change by the Earth system

Although increases in greenhouse gases stimulate climate change, the adjustments in temperature and precipitation lead to changes at the Earth's surface that amplify the change. Already, changes in climate since the Industrial Revolution have led to shrinkage of ice caps and glaciers in mountains worldwide, including the western mountains of Canada and Yukon and on our Arctic islands, where ice shelves have collapsed. Such loss of ice cover lowers the reflectivity of the Earth, so that more solar radiation is absorbed, and further warms the surface. A similar process occurs in spring when seasonal snow cover melts earlier or is less extensive across Canada. The process is best known for its effects on the shrinking Arctic Ocean ice cover and has remarkable local consequences. For example, autumn temperatures at the Arctic coast remain near 0°C until the ocean freezes. This is now regularly observed in the western Arctic. Another effect stems from the increase in frequency and severity of forest fires. In this case, evapotranspiration is curtailed due to the reduction of forest cover, so that available solar energy instead warms the soil and atmosphere. Carbon released by boreal forest fires is not usually counted as an emission because regrowth tends to reabsorb it over a few decades. Tundra fires, however, make a net emission because the time scale for peat to regrow is hundreds, not tens of years. A third effect from our current climate, which we now believe has started, is sufficient thawing of permafrost to initiate emissions from decay of organic matter entombed in frozen ground. This is potentially a very serious source of CO_2 and CH_4 . Previously, the permafrost environment trapped organic material in the ground. It is particularly relevant for Canada because after Russia we have the largest permafrost area. Organic-rich ground dominates the Mackenzie valley, NT, and the Hudson Bay Lowlands of Manitoba, Ontario, and Québec. Worldwide, the quantity of carbon in permafrost is estimated to be about 100 times as great as annual industrial emissions, so release of even a small fraction will counteract human efforts to limit emissions. Significant policy issues arise from the responsibility of governments under international climate protocols for human-sourced

emissions. Adjustments in “natural” earth systems, such as with forest fires or permafrost carbon, are not included in a country’s emissions totals, and yet these sources may outstrip current actions being proposed by governments. (396 words)

Suggested illustrations: reduced glacier area from the Coast Mountains, BC; burned forests; organic matter in permafrost

Consequences for the Earth system

The most immediate consequences of climate change stem from the increasing frequency and intensity of unusual and, at times, extreme weather events. These lead to flooding, especially in spring, as in Calgary (2013), eastern Ontario and Québec (2017), and New Brunswick (2018 and 2019); to drought, as in the Prairies in 1999-2004. In addition, the frequency of hurricanes has increased, with 19 of these major storms battering Canada in the 45 years between 1950-94, but, more recently, 24 hurricanes in 25 years since 1995. Excessive precipitation also promotes the conditions for landslides. Ocean acidification, due to uptake of CO₂ and its combination with water to form carbonic acid, is a global consequence that will negatively affect marine biodiversity and production.

In northern Canada, where permafrost restricts infiltration of precipitation, rapid flooding may occur after lengthy rainfall, as with the 14 washouts of the Dempster Highway in August 2016. In contrast, the many rivers of western Canada that depend on runoff from glaciers in the mountains are facing reduced flow in the summer as these ice fields melt away. Melting of the ice caps and glaciers also creates sea-level rise, raising the risk of flooding and destructive storm surges in communities near sea level such as Richmond, BC. The near-sea-level transportation corridor between New Brunswick and Nova Scotia with the Trans-Canada Highway and the CN Railway is particularly vulnerable at present. Erosion of our coasts will accelerate with rise in sea level. In the Arctic, the longer open water season has already led to more rapid erosion, threatening settlements such as Tuktoyaktuk. The steady warming has significant consequences for infrastructure built upon permafrost, not just for maintaining structures, roads and airport runways, but also for the hundreds of waste disposal sites, or sumps, created by petroleum exploration in 1960-2000 that were designed to use the surrounding permafrost as a secure containment.

The problems that stem from large magnitude precipitation events are commonly managed through emergency measures, but the gradual effects of climate change will be costly and will divert resources from other government programs, or force Canadians to accept a lower service standard from public infrastructure. There will be higher insurance costs for Canadians as fires and floods damage property. Many Canadians may appreciate the milder winters that climate change brings but not the higher waters, lengthened forest fire seasons and associated poor air quality in the elevated heat of summer. (400 words)

Suggested illustrations: Tuktoyaktuk coastline; Calgary floods; failed sump, NB-NS railway.

Climate challenge and social responsibility

Climate change is perceived as a controversial topic outside the scientific community. It occupies our political leadership and has resulted in a highly polarized debate across Canada. Within the scientific community, few people do not accept the basic principles laid out here. To the overwhelming majority of scientists, the evidence leads to a clear conclusion: **climate change is occurring at a rate that is unprecedented in human history**. Mitigation of the potential consequences of climate change requires a coordinated global effort simply because the atmosphere and oceans have no borders. There are human enterprises that may be adversely affected in the short-term by action taken to reduce emissions. Some of these organizations have acted to reduce confidence in scientific knowledge about the climate future while other organizations have used climate change to expand their influence. This has resulted in a polarized national and global debate that continues to struggle with the desire for healthy and robust economic development, improvements in quality of life such as housing, health care, and education while at the same time finding ways to reduce emissions and manage climate events such as spring flooding and destructive storms.

There has been and will be significant lobbying to affect and amend legislation, regulations and policies designed to address the climate challenge. We cannot be precise about our future climate decades from now, but we can trust the science because it has stood the test of historical examination of CO₂ and global conditions through the geological record, and because our scenarios of future climate simulations are based on validated physical understanding of the atmosphere-ocean-land system. Legislation, regulation, and policy development all need such science and a long-term commitment to mitigate climate change and its effects, while creating opportunities for nation building through innovative and aligned research and development.

As a society we must have open and transparent dialogue leading to action around climate change based on science. Climate change is a long-term issue and Canada has a unique position with our global geoscientific leadership to leverage research activities around climate change. Reduction of emissions is required as well as long-term technical adaptations driven by sound understanding of the current and predicted environmental effects from climate change. Practical measures such as improved environmental assessment techniques that include and mitigate effects from climate change for all municipal and industrial development are needed. For example, climate change issues such as water availability, forest fire potential, and flooding should be rigorously assessed prior to new housing development within cities and smaller municipalities. Building codes and strict zoning should protect Canadians from climate change effects especially in areas prone to forest fire or flooding. The national debate on climate change must evolve to avoid the polarization that currently exists across Canada.

The science is physically robust. In the long run, the sustainability of our social and economic system and of those organizations that may face short-term challenges depends on it. No Canadian individuals, institutions, enterprises, agencies, or governments should be

|

201 allowed to skip their responsibility to maintain a sustainable environment for our society. (509
202 words)
203
204 Total: 2336 words

Feedback Form - D1 Draft CFES Statement on Climate Change

Member Organisation (MO) - Name: _____

MO CFES Rep (CFES Councillor) - Name: _____

If different from the above, other designated MO contact for Statement on Climate Change development process

Name: _____ Email: _____ Phone#: _____

Please provide separate comments for each section of the draft statement (such as: - points missing / information incorrect / suggested removals / text improvement ideas, etc.). For each section, please also suggest further examples of Canadian climate change phenomena/events, and recommend examples from your MO and its membership that best highlight the critical roles of Canadian earth scientists in the understanding, management, mitigation and adaptation to climate change. (Where proffering other or additional facts, figures or published opinions, please briefly reference your source).

Does your MO have a Climate Change Statement or equivalent? Yes _____ No _____ (If Yes, please attach copy or provide link)

Firstly, please provide **General Comments** about the D1 draft text overall: _____

INTRODUCTION Section

Draft text comments: _____

Canadian event/phenomena examples: _____

Relevant role examples: _____

UNDERSTANDING THE SCIENCE OF CLIMATE CHANGE Section

Draft text comments: _____

Canadian event/phenomena examples: _____

Relevant role examples: _____

VALIDATION OF THE GREENHOUSE EFFECT BY THE GEOLOGICAL RECORD Section

Draft text comments: _____

Canadian event/phenomena examples: _____

Relevant role examples: _____

FOSSIL FUELS AND CLIMATE Section

Draft text comments: _____

Canadian event/phenomena examples: _____

Relevant role examples: _____

AMPLIFICATION OF CLIMATE CHANGE BY THE EARTH SYSTEM Section

Draft text comments: _____

Canadian event/phenomena examples: _____

Relevant role examples: _____

CONSEQUENCES FOR THE EARTH SYSTEM Section

Draft text comments: _____

Canadian event/phenomena examples: _____

Relevant role examples: _____

CLIMATE CHALLENGES AND SOCIAL RESPONSIBILITY Section

Draft text comments: _____

Canadian event/phenomena examples: _____

Relevant role examples: _____

Please provide **other general examples of Canadian contributions, initiatives or scientific endeavours relating to climate change understanding, mitigation, management, or adaptation** that you have not included above, that might be considered for inclusion: _____

Further Comments: _____

Thank You on behalf of the Board of CFES

NOTE: CFES will also be requesting similar feedback on the D1 Draft text from each of the CFES directors. All feedback received (from MOs and from Directors) will be tabulated and circulated, before revision work commences

Please submit your complete form to cfespresident@gmail.com by no later than 30 November 2020