

1 First authorship gender gap in the geosciences

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10 **Keywords:** science careers; gender bias; scholarly productivity; geoscience

11 **Abstract**

12 Although gender parity has been reached at the graduate level in the geosciences, women  
13 remain a minority in top-level positions. First authorship of peer-reviewed scholarship is a  
14 measure of academic success and is often used to project potential in the hiring process.

15 Given the importance of first author publications for hiring and advancement, we sought to  
16 quantify whether women are underrepresented as first authors relative to their representation  
17 in the field. We compiled first author names across 13 leading geoscience journals from January  
18 2013 to April 2019 (n = 35,183). Using a database of 216,286 names from 79 countries, across  
19 89 languages, we classified the likely gender associated with each author's given (first) name.

20 We also estimated the gender distribution of authors who publish using only initials, which may  
21 itself be a strategy employed by some women to preempt perceived (and actual) gender bias in  
22 the publication process. Female-author names represent 13-30% of all first authors in our  
23 database, and are significantly underrepresented relative to the proportion of women in early

24 career positions (30-50%). The proportion of female-name first authors varies significantly by  
 25 subfield, reflecting variation in representation of women across subdisciplines. In geoscience,  
 26 the quantification of this first authorship gender gap supports the hypothesis that the  
 27 publication process – namely, achievement or allocation of first authorship – is biased by social  
 28 factors, which may modulate career success of women in the sciences.

29

### 30 **Introduction**

31

32 First authorship of papers in peer-reviewed journals is crucial to academic success, promotion,  
 33 and competitive research funding (1,2). Authorship is key to moving up the career ladder from  
 34 graduate school to postdoctoral positions to faculty appointments (3). In the natural sciences,  
 35 women are underrepresented at the highest academic tiers (4–7). Representation of women in  
 36 academic geoscience drops off significantly at every successive tier, with the greatest  
 37 discrepancy at the highest ranks. This representation varies by career stage and subfield (40-  
 38 50% of Ocean, Atmospheric, and Earth Sciences graduate students (8), 30-36% at the assistant  
 39 professor level, and only 11.5-13% at the full professor level (6,7) are women).

40

41 A critical contributor to this gender gap is the transition from post-doc to the first faculty  
 42 position (9), and studies suggest this discrepancy results from differences in academic  
 43 productivity and perceived potential (3). While academic productivity, measured by publication  
 44 record, is often assumed to represent inherent scientific talent (10), the strongest predictor of  
 45 scholarly productivity is work environment, which highlights the importance of social factors in

46 determining academic success (11). For decades, publication analyses have revealed a  
 47 significant gender gap in authorship (12), publication in high impact journals (13), and citation  
 48 rates (14,15). While recent assessments document the persistence of a gender discrepancy in  
 49 first authorship of peer-reviewed publications in the sciences (4,5,16–18), an in-depth study  
 50 focused on the geosciences has yet to be done. Analysis of authorship imbalances contributes  
 51 to a stream of recent scholarship quantifying gender inequities in the geosciences at research  
 52 conferences (19,20), in peer review (21), and in recommendation letters (9).

53  
 54 Given the importance of first authorship for career advancement (3), we sought to assess the  
 55 extent to which female first authors are underrepresented among 13 of the major geoscience  
 56 journals. In this field, it is first authors who conventionally perform the majority of the research  
 57 and the writing. We used data-mining to quantify the representation of women as first authors  
 58 from January 2013 to April 2019 in leading geoscience journals (*Nature Geoscience*, *Geology*,  
 59 *Geological Society of America Bulletin*, *Journal of Geophysical Research (JGR) – all fields*,  
 60 *Geophysical Research Letters*, *Quaternary Science Reviews*, *Geochimica et Cosmochimica*  
 61 *Acta*). 62% of first-author names were categorizable by gender (Table 1).

62  
 63 One factor that potentially confounds any analysis of women’s representation in science is that  
 64 women may be more likely to initialize their given name in order to mask their gender as a  
 65 preemptive defense against implicit bias (as substantiated by studies showing that a name’s  
 66 gender influences competence assessments (22)). In this study, we compared initialed author  
 67 names to all authors in the complete mined database and identified the likely given name

68 based on coauthorship overlap. We then assigned a likely gender to these first authors with  
 69 initialized given names in order to assess the extent to which the practice of initializing names  
 70 impacts measures of women’s representation in the geoscience. We include open-access code  
 71 in a GitHub repository to reproduce this approach in future studies, because quantifying  
 72 authorship gender ratios will be useful to repeat for specific subdisciplines as well as to test for  
 73 change over time (see Materials & Methods).

74

75 **Results**

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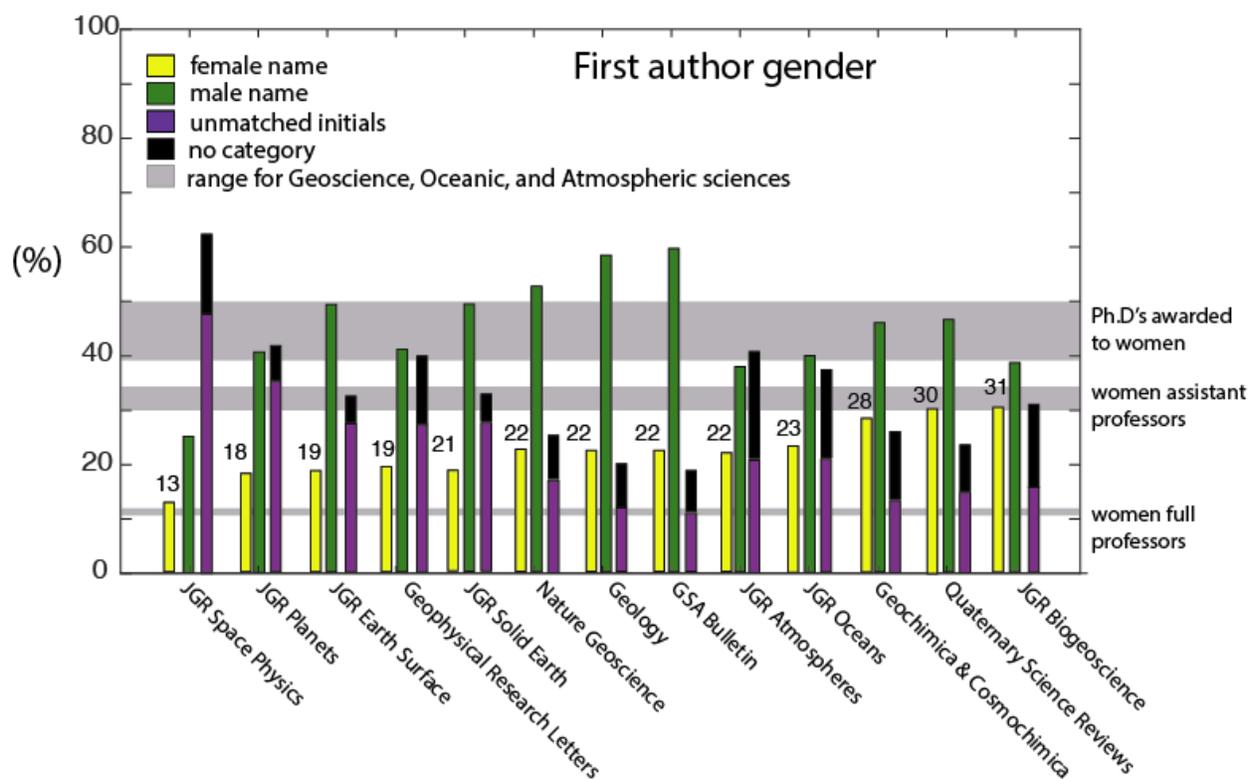
77 In the majority of journals analyzed (ten of the thirteen), female names made up fewer than  
 78 30% of gender-categorizable first-author names. The proportion of female name first authors  
 79 varies significantly by subfield, and likely reflects the representation of women across  
 80 subdisciplines. We found that female names represented at lowest, 23% of categorizable first  
 81 author names in *Journal of Geophysical Research Space Physics* (where representation of  
 82 women in student or early career positions is close to 20% (23)), and at most 36% of  
 83 categorizable first author names in *Journal of Geophysical Research Biogeosciences* (n =26,623  
 84 for categorizable first author names, excluding unmatched initials; see Materials & Methods)  
 85 across the journals analyzed (Figure 1; Figure 2).

86

87 Of the full database, including non-categorizable names, the percentage of female names  
 88 ranges from 13-30% across all journals. Male names (green; Figure 1) represent 25-61% of all  
 89 names, while uncategorized names (black; Figure 1) and unmatched initials (purple; Figure 1)

90 represent 5-16% and 11-48% of all names, respectively. Early career scientists, defined as those  
 91 who received their highest degree within the last 10 years, constitute the majority (~70%; see  
 92 Methods) of first authors in geoscience; however, the percentage of female names (13-30%) is  
 93 significantly below the representation of women at this career level (30-50%; translucent  
 94 purple bars; Figure 1; Figure 2).

95

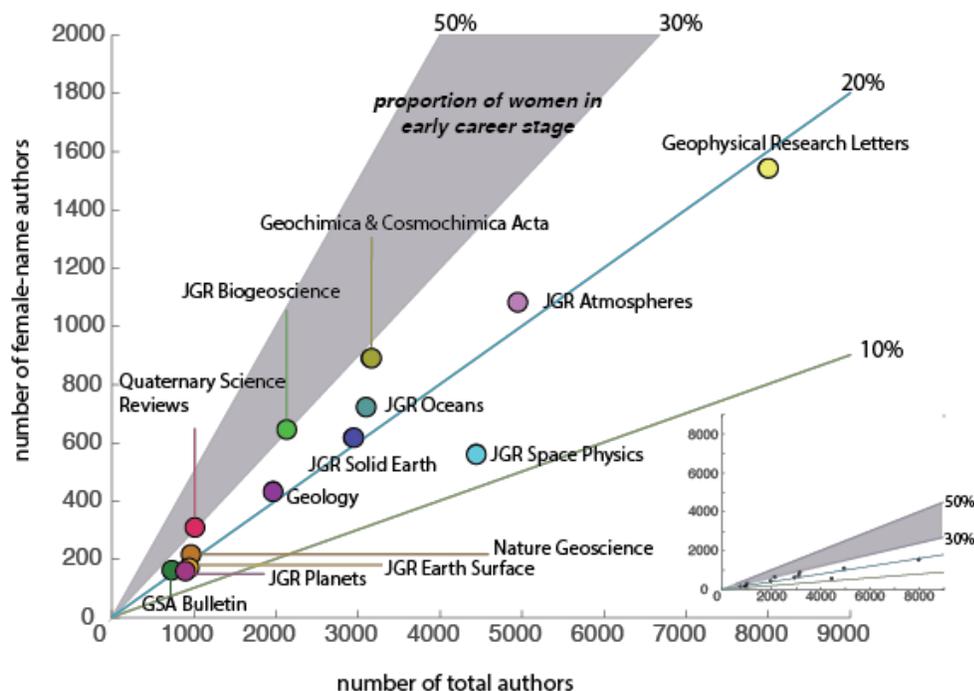


96  
 97 **Figure 1** | Representation (%) of female names (13-30%; yellow), male names (25-61%; green), unmatched initials  
 98 (11-48%; purple), and uncategorized (5-16%; black) non-ialed names in total first authors across geoscience  
 99 journals between January 2013 and April 2019. Female names (%) labeled for each journal. Light purple bars show  
 100 representation of Ph.D's awarded to women in 2016 (8), women assistant professors and women full professors (6,7)  
 101 in 2010 in Geosciences, Oceanic, and Atmospheric sciences.

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105

106 **Figure 2** | Proportion of female-name authors for each journal. Inset figure shows equal axes for number of total  
 107 authors and number of female-name authors. The purple shaded region spans 30-50%, the proportion range of  
 108 women in early career positions in geoscience (from women in assistant professor positions to women earning  
 109 Ph.D's). The green and blue lines represent the 10% and 20% proportion line, respectively.

110

111 Of the matched initialed given names, we found that 29% were categorizable as female names  
 112 (n =417, out of 1,434). This percentage varied by journal from 14% (*Geological Society of*  
 113 *America Bulletin*) to 41% (*Quaternary Science Reviews*). In *Geological Society of America*  
 114 *Bulletin*, female names represent 25% of all first authors, suggesting that men are more likely to  
 115 publish using initials in this journal, whereas in *Quaternary Science Reviews* female names are  
 116 slightly over-represented in initialed names (female names represent 36% of all first authors).  
 117 Although we are unable to match all initialed first author names, the percentage of female  
 118 names in matched initialed given names (29%) is proportional to the overall representation of

119 female names across all 13 journals (28%), indicating there is not a significant gender bias in  
 120 authors' decision to publish in the geosciences using only initials.

121

122 **Discussion**

123 Geoscience is not the only field with a first author gender gap. In other disciplines, a similar first  
 124 authorship gender gap was quantified by Bendels et al., including in the biological sciences  
 125 (female names represent 35% of first authors) and chemistry (female names represent 23% of  
 126 first authors); this gap persists across communities internationally (4). A study analyzing  
 127 neuroscience journals showed that female name first authorship only increased by 1% from  
 128 2006 to 2016 (17). Bendels et al. found a comparable first authorship gender gap in the Earth &  
 129 Environmental sciences (24%), and reported an annual growth rate of 1.8% for female name  
 130 first authorship (4). If we assume this growth rate of female name first authorship continues,  
 131 we estimate that parity would be reached in Earth & Environmental sciences in 2061.

132

133 The results from this study are limited by the range of journals selected for analysis and the  
 134 specific subfields of geoscience these journals represent. Future studies could reproduce this  
 135 analysis with other subdiscipline-specific journals using the open-access code provided from  
 136 this study in a GitHub repository (see Materials & Methods). One limitation to our approach is  
 137 the choice of gender-categorizing method and database. For example, genderize.io will not be  
 138 able to identify the gender for names pertaining to cultures where given names are not  
 139 gendered (e.g. some East Asian cultures). Furthermore, in this study, we compared our results  
 140 to the representation of women in geoscience within the United States, even though the author

141 names included in this study come from a range of international institutions, and the  
 142 proportion of women in different geoscience career stages varies by country.

143  
 144 We cannot draw a firm conclusion about what drives the identified disparity in first authorship  
 145 but we can speculate based on the existing literature. Biases may exist at many different stages  
 146 of the publication process. At the graduate school level, women may receive less mentoring or  
 147 encouragement to write and submit first-author research articles (24,25). A study analyzing  
 148 authorship in political science journals found a gender bias in the perception of likely  
 149 acceptance in journals, and therefore, in the ultimate decision to submit articles (26).

150  
 151 Double blind review, which is not widely used in the geosciences, has been shown to reduce  
 152 gender gaps in publication acceptance rates (27), although a study on peer review in ecology  
 153 suggests that reviewers do not rate papers differently based on first author gender in that field  
 154 (28). First authors may respond differently to a paper's rejection, as studies on confidence  
 155 suggest that men's self-assessment of competence is significantly higher than those of women  
 156 (29,30). Because of this higher level of confidence, men may be more likely to resubmit a paper  
 157 following a rejection, contributing to a higher rate of male first authorship in top journals. To  
 158 understand what causes our finding of a gender disparity in first author publication rates, it  
 159 would be helpful to understand disparities at different stages in the publication process in the  
 160 geosciences. Are women submitting fewer papers, are women's papers being rejected at higher  
 161 rates, or do women resubmit at lower rates compared to male counterparts? Answering these

162 questions would require journals to track gender (in addition to other social metrics such as  
 163 career stage) in submitted and accepted manuscripts.

164  
 165 As with gender, journals could consider other demographic sources of inequities such as race.  
 166 However, it is more tractable to infer the gender of given names than to identify race. For many  
 167 journals, first author demographics are not tracked at submission, and therefore self-reported  
 168 gender or race data are not available. Improved datasets documenting representation by  
 169 gender, race/ethnicity, sexuality, and nationality, across different career stages in a range of  
 170 disciplines, may help identify where biases exist in the publication pipeline (31).

171  
 172 Our findings support efforts to implement journal practices, such as double-blind review, which  
 173 reduce the impact of perceptions of first author gender and have been shown to increase the  
 174 success of women in publishing articles (27). In addition, mentoring is an important element in  
 175 academic productivity for early career scientists, and gender has been shown to influence the  
 176 degree of mentorship provided (25). The gender-pairing of faculty mentors with students can  
 177 result in different scholarly productivities (32), and links between gender, mentoring, and  
 178 publication might be highlighted by institutional leaders to raise awareness around social bias  
 179 in mentoring. Scientific communities might also consider other ways to recognize the various  
 180 contributions of authors, reevaluating the weight placed on first author publications (33).

181  
 182 Data documenting gender biases in the publication process in addition to studies identifying the  
 183 impact of social factors on productivity (1,2,26,30) challenge the view that science careers

184 advance solely on merit. Underrepresentation of female first authors relative to their presence  
185 in the geosciences contributes to a growing body of evidence that suggests success in science is  
186 strongly modulated by social factors (2), and that these factors influence tangible products such  
187 as first-authored publications. Efforts by journals, funders, and professional societies to  
188 understand what practices produce gender disparities in scholarly achievement will be required  
189 to reduce bias in and out of the publication pipeline.

190

## 191 **Materials & methods**

192 The code used to produce the results included in this study can be found at  
193 <https://github.com/kevindoyle/geoscience-first-authorship>. We compiled author names from  
194 January 2013 to April 2019 across a range of 13 geoscience journals (*Nature Geoscience*,  
195 *Geology*, *Geological Society of America Bulletin*, *Journal of Geophysical Research (JGR)*– all  
196 *fields*, *Geophysical Research Letters*, *Quaternary Science Reviews*, *Geochimica et Cosmochimica*  
197 *Acta*). We selected these journals to include a range of general geoscience journals as well as  
198 discipline-specific journals across Earth, Ocean, and Atmospheric Sciences. We web-scraped  
199 author and article names from each journal website (n = 35,183) by iteratively changing query  
200 parameters in the websites' search page URLs. The search result pages were rendered and  
201 downloaded using the Python package selenium (34). Author names and article titles were  
202 parsed from the downloaded pages by navigating the HTML tree using the python package  
203 BeautifulSoup (35). An author's given name was identified as the first token of an author's  
204 name string. Tokens were created using whitespace as a delimiter. Of these author names,  
205 24,525 are unique full names and 7,157 are unique given names. We classified the gender of

206 author's given names using the genderize.io API (36), accessed through a python client (37).  
 207 The genderize.io database contains 216,286 distinct given names across 79 countries and 89  
 208 languages. This library categorizes names as 'female', 'male', or 'uncategorized', and returns  
 209 the probability that the given name is classified as a specific gender. In running the scraped  
 210 author names through this database, we assigned the category 'female' or 'male' if the  
 211 probability was above 50% for the given gender. This approach is limited to gendered given  
 212 names, which may not hold across all cultures. Furthermore, this approach assumes the first  
 213 name is the given name, which is not true for some cultures where family names are the first  
 214 name.

215  
 216 Of 35,183 first author names, 9,994 names were initials (28%). To improve the accuracy of our  
 217 results, we attempted to identify the non-initialed given name of initialed authors. This was  
 218 done by comparing initialed names to all authors in the complete database of publications  
 219 across these 13 journals. For a given initialed name, we used the associated family name  
 220 (identified as the last token in the name string) to find all articles that included a coauthor with  
 221 that family name. We then compared the extent of overlap in coauthor names between the list  
 222 of articles containing this family name. The article with the greatest overlap in coauthorship  
 223 (minimum overlap of one) was selected to identify the given name of the initialed first author.  
 224 We were able to match 1,434 of 9,994 (14.3%) of initialed first authors. In calculating the  
 225 overall representation of female or male names, we combined the matched given names of  
 226 initialed authors with the remaining set of first authors who published using their non-initialed

227 given name (a total of 26,623 names). We then identified the likely gender of all compiled given  
 228 names.

229  
 230 We then compared these percentages to the representation of women at different career  
 231 stages in geoscience in the United States (translucent purple bars; Figure 1). Because  
 232 publications do not identify first-author career position (i.e., student, postdoc, faculty), we  
 233 could not categorize all first author names by likely career stage. To estimate the  
 234 representation of early career scientists in first author positions in geoscience journals, we used  
 235 a database of first-author names in American Geophysical Union (AGU) journals from 2013-  
 236 2018, which have been categorized for career stage. These stages are defined as student, early  
 237 career, mid-career, experienced, and retired. Here, early career stage is defined as those who  
 238 received their highest degree within the last 10 years or those within the age range of 30-39 if  
 239 no graduation date was provided. According to this database, 68% of first authors in AGU  
 240 journals from 2013-2018 were students or early career stage.

241

242 **Acknowledgments**

243 We are grateful to K. Blaufuss and B. Hanson for providing a dataset on first authorship  
 244 demographics in AGU journals. T. Pico acknowledges funding from Harvard University and NSF-  
 245 GRFP. The code used in this study is available in the following Git Hub repository:

246 <https://github.com/kevindoyle/geoscience-first-authorship>.

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Journal	Uncategorized	Male	Female	Unmatched initialed	Total
JGR Space Physics	644 (14.5%)	1114 (25.1%)	566 (12.7%)	2118 (47.7%)	4442
JGR Planets	58 (6.3%)	372 (40.6%)	166 (18.1%)	321 (35.0%)	917
JGR Earth Surface	45 (4.9%)	453 (49.2%)	171 (18.6%)	252 (27.4%)	921
Geophysical Research Letters	999 (12.5%)	3268 (40.9%)	1543 (19.3%)	2171 (27.2%)	7981
JGR Solid Earth	419 (14.3%)	1224 (41.8%)	618 (21.1%)	667 (22.8%)	2928
Nature Geoscience	77 (8.0%)	507 (52.5%)	217 (22.5%)	164 (17.0%)	965
Geology	153 (7.8%)	1145 (58.3%)	438 (22.3%)	229 (11.7%)	1965
GSA Bulletin	55 (7.5%)	435 (59.5%)	163 (22.3%)	78 (10.7%)	731
JGR Atmosphere	971 (19.6%)	1867 (37.7%)	1083 (21.9%)	1026 (20.7%)	4947
JGR Oceans	498 (16.1%)	1236 (39.9%)	723 (23.3%)	642 (20.7%)	3099

Geochimica & Cosmochimica Acta	392 (12.5%)	1443 (45.9%)	891 (28.3%)	418 (13.3%)	3144
Quaternary Science Reviews	181 (8.5%)	988 (46.4%)	646 (30.3%)	316 (14.8%)	2131
JGR Biogeosciences	154 (15.2%)	390 (38.5%)	310 (30.6%)	158 (15.6%)	1012
Total	4646 (13.2%)	14442 (41.0%)	7535 (21.4%)	8560 (24.3%)	35183

329

330 **Table 1** | Count for all names in journals scraped from January 2013 to April 2019. Proportions for uncategorized,  
 331 male, female, and unmatched initialed names are shown in parentheses. Journal of Geophysical Research is  
 332 abbreviated to JGR.

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