

1 **Title: Public communication by climate scientists: what, with whom and why?**

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Abstract

Public communication of science has increasingly been recognized as a responsibility of scientists (Leshner, 2003). Climate scientists are often reminded of their responsibility to participate in the public climate debate and to engage the public in meaningful conversations that contribute to policy-making (Fischhoff, 2013). However, our understanding about climate scientists' interactions with the public, and the factors that drive or inhibit them, is at best limited. In a new study, we show that it is the most published and not necessarily the most senior, that often talk in public, and it is primarily intrinsic motivation (as opposed to extrinsic reward), that drive them to engage in public communication. Political orientations, academic productivity, and awareness of controversy the topic raises in the public domain were also important determinants of a climate's scientist public activity. Future research should explore what is required to protect the intrinsic motivation of scientists.

Keywords: science communication, surveys of scientists, public engagement, climate change

42 **1 Introduction**

43 Climate change communication and its effects on society have been examined through analysis of
44 media frames and coverage (Schäfer & Schlichting, 2014; Boykoff, 2007), policy discourses
45 (McCright & Dunlap, 2011), framing of debates (Nisbet, 2009; Moser, 2010), and most of all, in
46 analysis of public understanding, attitudes, values and behaviour towards the climate problem
47 (Pidgeon, 2012; *The Politics of Climate*, 2016; Kahan et al., 2012). What has received little attention
48 in climate communication is the supply side: how climate scientists are engaging with the public.
49 Highly regarded and trusted on the causes of climate change (Kahan *et al.*, 2012), and major actors in
50 the climate debate, this is somehow surprising. To date, the existing literature is scarce and has mostly
51 focused on case-study analyses of specific forms of engagement including climate scientists' uses of
52 traditional news media (Ivanova *et al.*, 2013; Post, 2016, Tosse, 2013) and social media networks
53 (Schäfer, 2012), stakeholder engagement (Anderegg *et al.*, 2010; Prokopy *et al.*, 2015; Wilke and
54 Morton, 2015), and to a lesser extent, behaviours of climate scientists or what mobilizes them to go
55 public (Sharman and Howarth, 2017, Hosse, 2013). These studies point to a close relationship between
56 climate scientists and the media, despite only a small number interacting with journalists frequently or
57 contributing to policy (Lehmkuhl, 2012), often high-ranking scientists with a stronger focus on climate
58 research and social scientists (Ivanova et al. 2013, Bray & von Storch, 2007, 2010). When it comes to
59 content, climate scientists choose not to communicate uncertainties about climate change to
60 journalists, distancing themselves from environmentalists and other interest groups (Post, 2016), and
61 political purposes (Tosse, 2013). Despite the contribution of these studies to our understanding of
62 climate scientists' media interactions, a survey based analysis of the broader public communication
63 activity and motivations of climate scientists has not been conducted and would allow for an
64 understanding of the degree of mobilisation for public engagement of this community and factors that
65 drive that mobilisation, and inform future discussions on climate public engagement. This would then
66 inform other analyses that focus on the audience side – what various publics take away from
67 interactions with climate scientists.

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69

70 **2 Background**

71 Previous studies of scientists have pointed to public communication being an elitist activity amongst
72 the most senior (Dunwoody and Scott, 1982; Dunwoody and Ryan, 1985; Jensen, 2011) academically
73 productive (Dunwoody and Scott, 1982; Bentley and Kyvik, 2011), male scientists (Crettaz von Roten,
74 2011). Some limited studies suggest that scientists used as sources by reporters tend to be those in
75 positions of authority (deans, directors, department heads) rather than necessarily those with the best
76 expertise for the topic (Shepherd, 1981). To explain why communication is performed actively only
77 by a minority, scientists blame lack of communication skills, time, institutional support, and
78 recognition to greater involvement (Royal Society, 2006; Peters *et al.*, 2008; Dunwoody, Brossard and
79 Dudo, 2009); they say, however, that they would be willing to engage more with the public if there
80 were rewards and recognition for their work (Royal Society, 2006), with many recognised scientific
81 institutions having created prizes and grants to motivate more scientists to communicate (e.g. RS,
82 AAAS, RCUK). Despite the contribution to understanding the communication practice of the
83 individual scientist, the empirical evidence remains inconclusive and sometimes contradictory. Few
84 studies have relied on a theoretical framework that allows to understand what factors are most
85 important in scientists' public communication. And, those that do, have considered scientists'
86 intentions as measured by a scientist willingness to participate rather than his/her actual behaviour
87 (Poliakoff and Webb, 2007; Besley, Oh and Nisbet, 2012). But, intentions to participate do not explain
88 why scientists communicate, and might not be reflected into behaviour. For example, enjoyment has
89 been identified among medical scientists' as an important motivation for their interactions with the
90 media (Peters *et al.*, 2008), but enjoyment does not seem to feature as an important predictor of
91 nanoscientists' intentions to engage in public communication (Dudo *et al.*, 2014), a claim which might
92 be based on attitudes, descriptive norms and perceived behavioural control (Poliakoff and Webb,
93 2007). This may be an indicator that it requires more than intentions for a scientist to engage with the
94 public, it may also be a result of disciplinary cultures. General studies of scientists point to different
95 disciplinary cultures in science communication with fields less likely to engage with the public such as
96 the natural sciences and engineering (e.g. (Kreimer, Levin and Jensen, 2011, Johnson, Ecklund and
97 Lincoln, 2014) and engaging in different formats of engagement. Far less is known about the factors

98 that drive these differences across scientific disciplines within broad scientific areas. Recent work by
99 Entradas and Bauer (2017) has pointed to significant differences in the engagement practice of natural
100 scientists, with some disciplines very much engaged with the public and others less. Much then
101 remains to be understood about the influence of each factor on a specific community's behaviour, and
102 most importantly, how internal and external factors behave in specific communities when considered
103 together. Better understanding of these factors might suggest analyses that focus on audience reception
104 of communication by and with scientists. Here we consider scientists' reported participation/non-
105 participation in climate science communication and challenge some of the previous findings.

106 Our approach to communication uses a framework model derived from Lewin's long-standing
107 generic model of behaviour that takes into account the total situation (Lewin, 1936, 1951). Similarly,
108 we consider *communication activity* (C) a function of the person-in- context. On the person side (P)
109 this includes his/her psychological orientations towards public communication, and on the context
110 side, we refer to the social situatedness (S) or positioning of the communicator in his/her social space.
111 This can be conveniently expressed with the formula *communication activity* $C=f(P, S)^1$. Here we are
112 saying that scientists' communication activity (C) is a function of personal factors (P), and situational
113 factors (S) combined, and this combination might be a characteristic of a specific scientific community
114 such as the climate scientists. By personal factors (P), we mean perceptions, opinions, beliefs and
115 motives that indicate commitment to public communication; by situational factors (S) we refer to
116 indicators of the person's positioning in his/her social space (environment) including gender,
117 hierarchical position on the job, and academic productivity, which characterize the context of
118 communication activity. This framework comprises factors often correlated with scientists' public
119 communication: (P) are the subjectively expressed indicators, while (S) brings together the more
120 objectified indicators. Other objective (S) factors could include features of the organisational context
121 such as help from PR officers and funding (Entradas and Bauer, 2018, Marcinkowski et al., 2013). We
122 included motives and perceptions because they are covariates of actual behaviour (Deci and Ryan,
123 1985), and they are particularly relevant in the context of controversy (Peters *et al.*, 2008). This
124 framework is then helpful to think about the influence of these two sets of conditions in scientists'
125 communication behaviour and can provide insights into the choices of climate scientists to

126 communicate, which might be useful to further the involvement of scientists' in public
127 communication.

128

129 **3 Methods**

130 We studied a sample of climate scientists, members of the American Geophysical Union (AGU), with
131 a twofold goal: to characterize what and with whom climate scientists communicate, and to examine
132 what factors explain the variance of that participation.

133

134 **3.1 Procedure and sample**

135 An online survey was conducted between March and end April 2016 with AGU active researchers in
136 climate research (N=3679). Respondents were selected according to scientific area focusing on those
137 whose research is connected to climate change. The list comprised members from the AGU Ocean
138 Sciences only, whose research focused on studying the role of ocean in the climate system. After data
139 cleaning, the total sample consisted of 425 respondents, for a response rate of 12%. The majority of
140 the respondents were male (67%, N=256) and 33% were female (N=128); 63% (N=252) were in
141 senior positions and 37% (N=148) were junior; the average number of publications in the previous
142 five years was 10.5 (N=394, sd=10.6). Most were employed in Public Research Universities (45%,
143 n=190), Government Agencies (22%, n=93) and private Research Universities (9%, n=40); and a
144 minority worked for NGOs or non-profit organizations (8%, n= 32), private companies (7%, n=29) or
145 other university/college (10%, n=40). The average number of researchers per host institution is 1926
146 (n=417, SD=4130.8) and 83 per research institution (n=400, SD=393.5).

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148 **3.2 Measures**

149 *Dependent variable*

150 *Participation* was given by the reported participation/non-participation in public engagement
151 activities, coded (1) for participation and (0) for non-participation. We asked scientists whether they
152 had participated in public engagement activities in the previous year. We then asked communicators

153 for counts regarding their participation in various types of public events, news media channels and
154 social media, in the previous year; and about the frequency of contact of various types of audiences
155 (See SI for full description). To address our second goal, we measured explanatory factors identified
156 in previous studies including socio-demographics, perceptions and motivations, and others thought
157 could be particularly important to this specific community such as perceptions on controversy as
158 described below.

159

160 **Independent variables**

161 *Awareness of controversy & political orientations*

162 Because it is still an open question whether public controversy over contested areas encourages or
163 discourages scientists to get involved in public communication, we measured scientists' awareness of
164 the level of controversy their topic raises in the public domain. Respondents were asked to
165 agree/disagree with the item 'My research is controversial in the public domain' on a 5-point scale
166 ranging from 1 (strongly disagree) to 5 (strongly agree). Of the respondents, most agreed (47%
167 (n=197) with the statement and 29% disagreed (n=121) (see TabS1, SI). *Controversy* indicates the
168 degree to which respondents believe public is aware of controversy and is used as a continuous
169 variable.

170 We also measured scientists' political orientation. Nisbet and Markowitz (2015) show no
171 effect of political ideology on public engagement among AAAS scientists across disciplines (but this
172 may be a result of the small n as only 6% indicated their principal field geosciences. There is general
173 scientific consensus on human causation of climate change (Alley et al., 2007; Farnsworth and
174 Lichter, 2012; Bray and von Storch, 2016) – for instance, Bray and von Storch (2016) in an
175 international survey of climate scientists found that 87% are to some extent convinced that climate
176 change is, or will be, the result of anthropogenic cause. Yet, conservative political views have been
177 found to associate with stronger beliefs that climate change is not happening (McCright and Dunlap,
178 2011a), which could impact on scientists' public communication. So we wanted to examine climate
179 scientists' political orientations and whether they were a driver of communication. Respondents were
180 asked to indicate their political orientation on 5 options ranging from very conservative to very

181 progressive. Most respondents (74%, n=270) hold progressive views, 24% moderate, and 3%
182 conservative (see TabS1, SI for respondents' characteristics). The variable was recoded into a dummy
183 with (0) for non-progressive and (1) for progressive.

184

185 *Motives*

186 Motives have been used without a consistent approach in previous studies. We chose to use a well-
187 developed approach, distinguishing between *internal* and *external motivations* (Deci and Ryan, 1985).
188 Intrinsic motivation refers to performing an activity simply because it is interesting, brings enjoyment
189 and is satisfying, as opposed to extrinsic motivation, which refers to doing an activity because it leads
190 to an external outcome (e.g. fulfilment of role, public support). Moreover, we differentiate two
191 extrinsic motives: 'rewards' such as awards and prizes which can be expected from participating in
192 engagement activities (Royal Society, 2006a), and 'role', i.e. activities that arise from scientists'
193 understanding of their role in public communication as academic researchers (Mead and Morris, 1967;
194 Dudo and Besley, 2016). Construct *motivations* were measured with 12 items, which were assessed
195 using 5-point Likert-scales, ranging from 1 (strongly disagree) to 5 (strongly agree) (see Tab3, SI, for
196 respondents' responses to motives items).

197 Exploratory factorial analysis (EFA) resulted in a reliable scale for the construct 'motive'
198 (Cronbach's $\alpha=0.78$) with items loading appropriately in three factors. The internal consistency of this
199 structure was further confirmed with confirmatory factorial analysis (CFA), ($\chi^2=104.39$, $df=51.00$,
200 $\chi^2/df=2.05$, CFI=0.99, RMSEA=0.05) (see TabS4a and S4b, and Figure S1). The factors were
201 labelled '*intrinsic motivation*', degree to which respondents enjoy public communication; *extrinsic*
202 *motivation 'role'*, degree to which respondents believe they have an obligation for public
203 communication; and '*extrinsic motivation reward*', degree to which respondents are seeking prizes or
204 recognition. Indices for high and low motivations were constructed using CFA scores (median split):
205 'intrinsic motivation' 'extrinsic motivation role' and extrinsic motivation reward were coded (0) for
206 *low* (below the median) and (1) *high* (above the median) level of motivation.

207

208 *Public perceptions*

209 Questionnaire measures of the construct perceptions of the public included 8 items, positively and
210 negatively worded, which respondents were asked to agree or disagree in a 5-point Likert scale
211 (strongly disagree=1 to strongly agree=5) (see TabS5, SI for responses for these items and percentage
212 of the respondents agreeing with each statement). These items were informed by studies in the PUS
213 literature that point to the importance of views on the public to scientists' communication, in particular
214 views about the public participation in policy making (e.g. Entradas, 2016), which we thought could
215 be particularly relevant to a community involved in controversy.

216 Principal Components Analysis (PCA) and CFA (Confirmatory Factorial Analysis) loaded in
217 two factors showing a strong fit to the data ($KMO=0.72$; $\chi^2=18,23$, $df=13$, $\chi^2/df=1.40$, $CFI=1.00$;
218 $RMSEA=0.03$) (see Tabs 5, SI). Factors were labelled '*deficit*' (degree to which respondents believe
219 public are interested and know about science), and '*participative*', degree to which respondents
220 believe public should participate in climate science policy making. Indices for the two factors were
221 constructed using CFA scores (median split) and recoded into negative (0) and positive (1) images of
222 the public according to agreement/disagreement to the public level of interest/knowledge in science
223 and their public for decision-making.

224 Respondents were also asked contextual information such as *gender*, *seniority positioning in*
225 *the organisational hierarchy*, and *academic productivity* as given by the number of peer-reviewed
226 publications produced over the previous 5 years; academic productivity was recoded into a binary
227 using median split '>= 8 publications' '< 8 publications', and seniority was recoded into a binary
228 'junior' and 'senior' (see TabS1, SI).

229

230 **3.3 Analysis**

231 We considered social situatedness (S) with gender, seniority and academic productivity, and personal
232 orientation (P) with the perceptions of the public, motives to communicate and political orientations of
233 scientists (conservative vs progressive). We investigated the relative influence of (P) and (S) variables
234 on scientists' participation in four models using logistic regression. We are modelling the likelihood of

235 a scientist being a communicator versus non-communicator using the constructs described above and
236 dependent variable ‘participation’.

237 Models 1, 2 and 3 show the independent influence of each set of factors on participation, and
238 Model 4 shows which factors are the most important determinants of participation when both (P) and
239 (S) are considered. All sets of variables explain a significant amount of the variance in the outcome
240 variable, which increases from model to model, reflecting the importance of each set of variables
241 separately, and uncovering the most significant drivers of scientists’ engagement in public
242 communication (Tab1).

243 Variance Inflation Factor (VIF) was used to test for multicollinearity among predictors. We
244 report Nagelkerke’s R2 and the predictive accuracy indexes of the models. Reference categories for
245 our predictors were as follows: *female* for gender, *senior* for seniority, *>= 8 publications/5 years* for
246 academic productivity, *progressive* for political orientation, *positive* image for variables *deficit* and
247 *participation* and *high* for intrinsic and extrinsic motivations by ‘role’ and ‘rewards’.

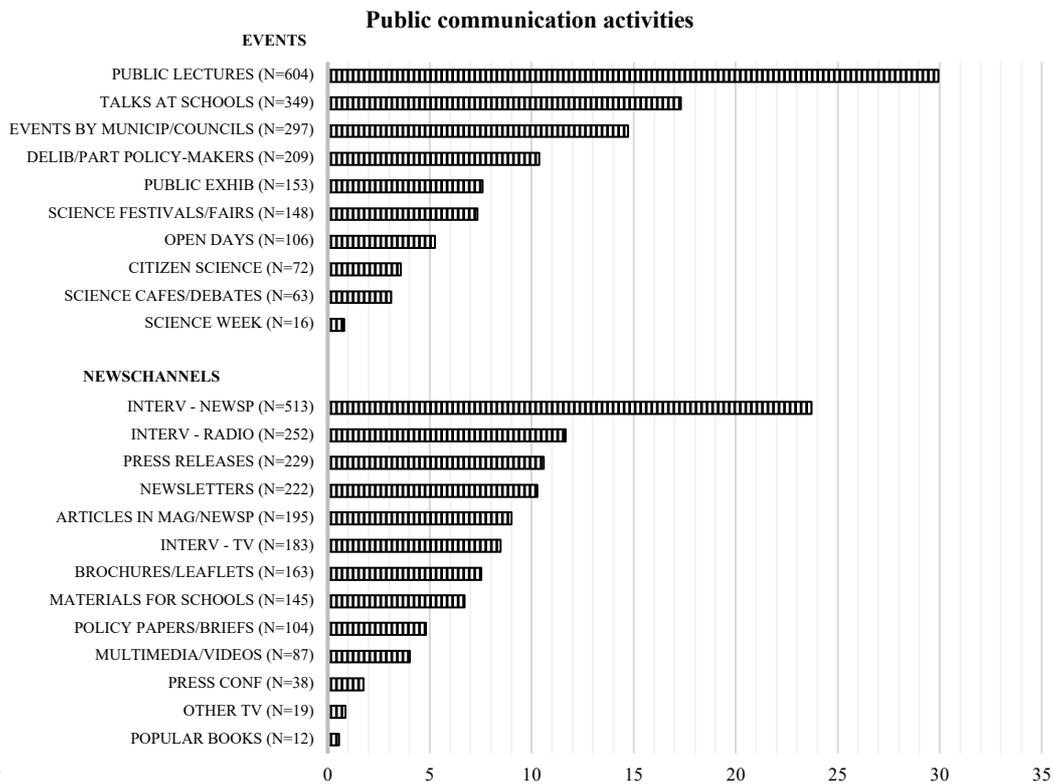
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249 **4 Results**

250 **4.1 Public communication activity of climate scientists**

251 Our data show that climate scientists have an intense interaction with the public: 73% of all
252 respondents said they had engaged in public communication initiatives in the past 12 months (N=308);
253 the average number of activities per active researcher per year was 14 activities (the median is 9
254 activities). This represents an average of 9 public events and 5 media contacts per active climate
255 scientist. Comparatively, participation in public events is more common than media interactions.
256 Yet, only 33% of climate scientists can be considered ‘highly active’ (i.e. engaging above the
257 average), showing a diverse mobilisation of climate scientists with some performing very much above
258 average and others very much below. Notwithstanding, these numbers are high when compared with
259 studies of natural scientists: for example, Jensen (2011) found 0.8 activities per environmental French
260 scientist (Jensen, 2011), and Entradas and Bauer (2017) found 0.6 activities per Portuguese natural
261 scientist (Entradas and Bauer, 2017); while studies across all scientific areas show a 10% of ‘highly
262 active’ communicators (Dunwoody and Scott, 1982; Royal Society, 2006). Methodological

263 differences, in particular the broad research areas considered, could in part explain this gap in the
 264 results. Yet, the public communication activity found among AGU climate scientists is similar to that
 265 found amongst other communities of climate scientists. In 2012, 67% of German climate scientists
 266 reported at least one contact with news media (of these, 12% reported more than six contacts), 47%
 267 with a policy actor, and 54% had contacted with a non-governmental organisation (Ivanova et al.,
 268 2013). Importantly, these studies including ours presented here, suggest a community of highly
 269 engaged communicators amongst climate scientist. The high public communication activity found
 270 amongst climate scientists and astronomers (Entradas and Bauer, 2018), put into perspective general
 271 claims that natural scientists communicate less than social scientists. This highlights the need to study
 272 specific communities to better understand their unique characteristics.



273 Fig1a

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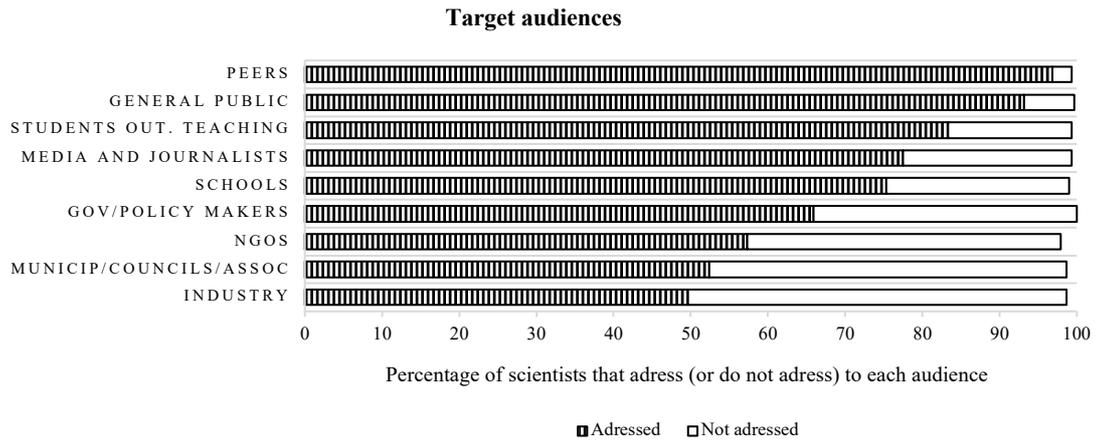


Fig1b

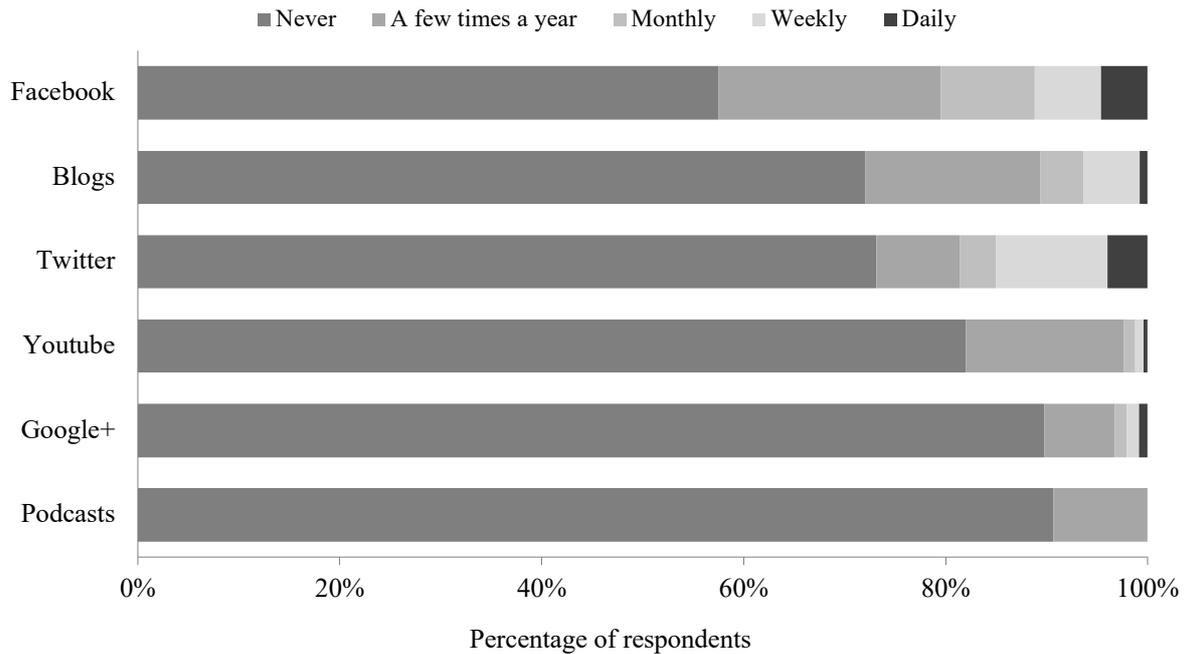
Fig 1. Fig 1a shows the type and intensity of public engagement activity – public events and news media channels, as reported by scientists. We present the total counts for each activity (N= in each row label), and within each group of activities. The bars in the chart show the percentage which that activity represents of the total, taking all activities in that group as the basis for 100%. For example, amongst all types of events, 30% of the events in which climate scientists engage are public lectures. A total of 4179 public communication activities were reported. Fig1b represents the frequency of scientists’ contact (or no contact) with different audiences. Data are self-reported estimates and should be interpreted carefully.

Fig1a shows that the most popular public events in which climate scientists participated were public lectures and talks at schools followed by workshops with local government/councils and participatory events in policy makingⁱⁱ. While high levels of involvement in two-way policy-oriented events are have not commonly been found amongst natural scientists (Entradas and Bauer, 2017), the high level of involvement of climate scientists in such events is perhaps not surprising given the high politicization of climate change (Alley *et al.*, 2007), which often involve scientists. Climate scientists’ level of contact with the media is also high when compared with other (even controversial) disciplines. For example, 44% of the surveyed climate scientists reported more than two contacts with news media channelsⁱⁱⁱ, compared to 33% of German medical researchers (stem cells and epidemiologists) who reported more than two contacts a year (Peters *et al.*, 2008), a further indicator of the medialization of climate science (Boykoff, 2011; Ivanova *et al.*, 2013). Although methodological aspects do not allow for direct comparison, the intense media activity of climate scientists is found in other countries as

306 well, suggesting an active community in the climate public discussion, regardless of country. In 2012,
307 41% of the German climate scientists contacted with a newspaper and 33% with the radio. Among our
308 respondents, 47% contacted at least once with a newspaper and 32.8% with a radio. This may be
309 explained by the internationalization of climate change, a social, political and scientific issue that
310 impacts on the lives of every citizen. Also, consistent with previous studies (Schäfer, 2012), we found
311 that social media channels are not much in use by climate scientists for public discussion, with the
312 large majority reporting they never used them; within that smaller set, Twitter was amongst the most
313 used, Facebook and blogs were used a few times a year (Fig2). Contrary to traditional communication
314 means, social media networks are more in use by less academically productive scientists (e.g. 9% of
315 highly ranked respondents reported using Twitter weekly or daily versus 20% of lower ranked
316 scientists) ($p < 0.01$). Despite the big promises of social media to engage the public in conversations
317 about climate science, these communication means do not seem to have yet been adopted by scientists
318 – if they ever will. Within the whole picture, traditional means are preferred. While we cannot fully
319 explain the reduced use of social media by climate scientists, one possible explanation is climate
320 scientists' fear that their results are misinterpreted by the public or journalists or exploited by interest
321 groups (Post, 2009), which inhibit them to use these fast propagators of fake news (Vosoughi, 2018).

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326 **Fig.2** Frequency of use of social media networks by climate scientists. Percentage of respondents who reported using each of
 327 these means are shown

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329 **4.2 Understanding drivers of scientists' climate engagement**

330 Corroborating previous surveys on scientists across disciplines (Dunwoody and Ryan, 1985; Jensen,

331 2011) we show that, when (S) factors are considered alone (Model 1), also in climate science

332 communication it is the more senior and academically productive scientists that communicate more.

333 Ivanova et al. (2013) found media interactions more common amongst high-ranking climate scientists.

334 The fact that the most senior and reputable scientists are often those sitting on committees and

335 advisory policy panels, and requested for media interviews (Peters *et al.*, 2008; Crettaz von Roten,

336 2011) could in part explain these effects. But these findings are challenged when (S) factors are

337 combined with (P) factors (Model 4): Seniority loses significance and academic productivity remains

338 significant, suggesting that academic productivity is a more important factor than seniority. It is then

339 the most published and not necessarily the most senior climate scientists that often talk in public.

340

Independent Variables	Model 1			Model 2			Model 3			Model 4		
	Estimate	SE	Wald	Estimate	SE	Wald	Estimate	SE	Wald	Estimate	SE	Wald
Gender (Female)	-0.265	0.263	1.012							-0.142	0.305	0.216
Seniority (Senior)	-0.643*	0.253	6.452							-0.513	0.301	2.894
Academic product (>=8 /5 year)	-0.594*	0.243	5.974							-0.818**	0.290	7.978
Political Orientation (Progressive)				-0.833***	0.238	12.288				0.829**	0.288	8.277
Perceptions on controversy (not)				0.304**	0.100	9.214				0.319**	0.118	7.28
Deficit (positive)				-0.42	0.232	3.277				-0.740	0.278	0.070
Participation (positive)				-0.65**	0.213	7.904				-0.372	0.274	1.848
Intrinsic Motiv (high)							-1.635***	0.319	26.235	-1.915***	0.385	24.781
Extrinsic Motiv (Role) (high)							-5.68	0.313	3.287	-0.512	0.376	1.852
Extrinsic Motiv (Rewards) (high)							0.494*	0.230	4.623	0.159	0.273	0.341
(Intercept)	1.579	0.303	27.105	0.643	0.407	2.492	1.661	0.230	52.087	2.381***	0.617	14.914
Nagelkerke R ²	0.058			0.169			0.255			0.395		

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343 Note: *p < .05, ** p < .01, *** p < .001. Dependent Variable 'participation': 'Do you undertake any public communication activities for the
344 non-specialist public? For example, do you maintain a website/blog/social media for the public, participate in science cafes, give talks at
345 schools, give public lectures, respond to media inquiries, etc.?'
346

347 **Tab1.** Tab1 shows binary logistic regression models representing the predictive power of S and F factors on scientists'
348 participation in public communication. Reference categories are represented in brackets. By order of magnitude, Model 4
349 shows that the most important drivers for a scientist to engage with the public are intrinsic motivation, political orientations,
350 academic productivity, and awareness of controversy. Moreover, Model 4, explains 40% of the variance of scientists'
351 participation in public communication offering a strong fit when compared to previous studies, which have analysed
352 constructs separately.
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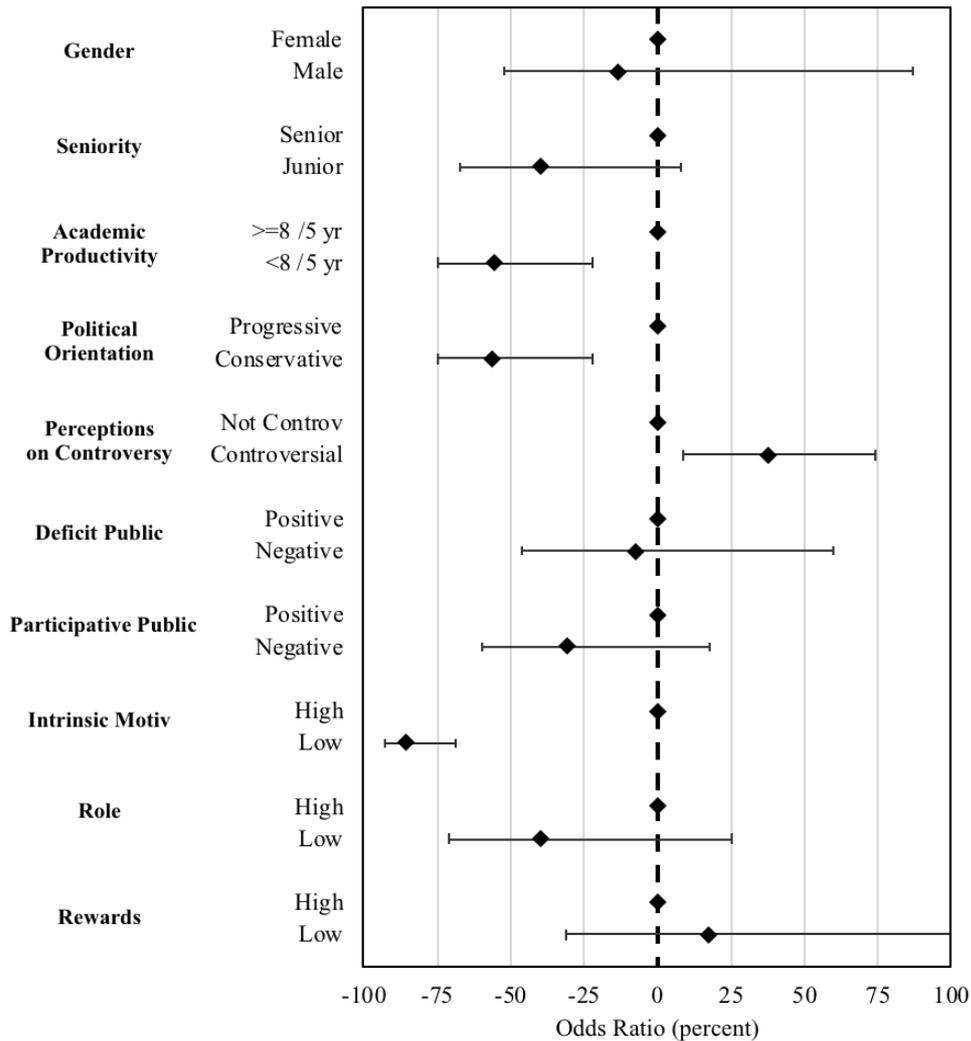
354 We also show that views of the public matter (Model 2). Perceptions of a deficit public do not
355 influence participation, perhaps given that an image of an interested, trusting public prevails over a
356 deficit one, but images on the role of the public in contributing to research and policy do. Those
357 thinking that the public should be involved in climate research and policy discussions were 46% more
358 likely to engage in public communication than those holding negative views on public participation;
359 but this is the view of a minority (e.g. only 18% agreed that the public should not be involved in the
360 decisions about their research; see Tab5, SI). And, this relationship loses significance in Model 4.

361 Motivations both intrinsic and 'rewards' were strong predictors of participation (Model 3).
362 Those engaging with the public were those more likely to be highly motivated while also less likely to
363 perceive extrinsic rewards as important. This suggests that rewards, while not important drivers for
364 those already engaging in public communication, may work as a barrier for those who do not engage,

365 particularly for younger, less productive researchers. In fact, rewards lose significance in Model 4.
366 Dunwoody, Brossard and Dudo (2009)'s study with US stem cells researchers and epidemiologists
367 interacting with the media, found no associations between perceptions of extrinsic rewards and
368 intensity of scientists' contact with the media (an activity of the most senior), but rewards were valued
369 by Spanish young researchers attending a science fair (Martín-Sempere, Garzón-García and Rey-
370 Rocha, 2008). 'Role' was not significant. We found no significant differences in the perceptions of
371 'role' of those who publicly engage and those who do not. This does not mean however that scientists
372 did not see public engagement as part of their role. In fact, only a minority saw 'public engagement as
373 a hobby' (16%). In other words, some scientists despite not participating recognise public engagement
374 as part of a scientist's role.

375 When both (P) and (S) factors are in the same model (Model 4), intrinsic motivation explains
376 most of the variance in scientists' engagement with the public (Wald=24.8), followed by political
377 orientations (Wald=8.3), academic productivity (Wald=8.0) and views on controversy (Wald=7.3),
378 seniority is not significant (Fig3). That is, it mainly is the self-enjoyment and satisfaction that public
379 communication activities bring that turn scientists to the public. A highly intrinsically motivated
380 scientist is 85% more to engage in public communication. This corroborates findings from previous
381 studies that have found enjoyment to be an important factor (but not the most important) in scientists'
382 interactions with the media (Dunwoody, Brossard and Dudo, 2009). Our study indicates that when it
383 comes to actual participation, it is the satisfaction that scientists feel that matters most while external
384 motivations are not likely to drive scientists to public communication initiatives. This is interesting.
385 Enjoyment has been often identified as an important feature in scientists' public communication, but
386 its explanatory power has been rarely discussed. Comparable data would be needed to conclude on
387 whether these features are specific of this community or are found elsewhere.

388



389

390 **Fig3.** Forest plot showing binary logistic regressions for communication activities when both (P) and (S) variables are
 391 considered (Model 4). Dependent variable is participation/non-participation. Model include ‘communicators’ only. Data
 392 correspond to odds percentage ratios and 95% CIs. The plot presents the likelihood of being a performer in public
 393 communication. Diamonds represent the odds % and the whiskers the CIs. Significant associations are shown when CIs do
 394 not overlap with 0. Diamonds on the line are the reference categories.

395

396 Also, the awareness of controversy is an important factor. Climate scientists perceiving their
 397 topic as controversial in society were 37% more likely to engage with the public. This is expected, as
 398 those more aware of the controversy of climate change also have a higher sense of responsibility for
 399 communication and may be moved by an aspiration to counteract public disbelief in climate change.
 400 Scientists’ engagement is also a function of political orientations, with those holding more progressive
 401 views also being more likely to engage in public communication (56% more likely). It is possible that

402 those scientists with more progressive political views, perceiving the risks of climate change more
403 seriously (Farnsworth and Lichter, 2012), take responsibility for public communication either as an
404 attempt to correct public misconceptions and convert those more skeptical members of the public, or
405 because they fear that a public that does not believe that climate change is human caused (Weber and
406 Stern, 2011) is less likely to support government commitment to international climate policies. It is
407 interesting to note that most scientists surveyed (57%) agreed they ‘should engage with the public to get
408 the attention of policy-makers as policy makers respond more to the public than to scientists’ (12%
409 disagreed), while also agreeing that their research ‘has implications to policy makers’ (87%). This seems
410 to suggest that the public is seen as a means to influence policy. This could however be unique of this
411 community and the United States context, where scientists may face more challenges to communicate
412 climate change to a society where half of the public rejects that climate change is caused by human
413 activity (Roser-Renouf et al., 2016) and a country that has recently withdrawn from the Paris Agreement
414 on Climate Change pointing to a political disbelief in climate change.

415

416 **5 Discussion and Conclusion**

417 We identified the public communication activity of the AGU surveyed climate scientists and relative
418 contribution of (P) and (S) factors to the variance in their public participation activity. Our findings
419 have implications for the practice of communicating climate change and science communication
420 research more broadly. Firstly, we found that the surveyed climate scientists are active public
421 communicators, with dynamic relations with the public, the media and policy actors, while engaging
422 in both one way and two-way types of public communication approaches, some policy-related. We
423 cannot, however, conclude on the quality of such interactions and whether this involvement leads to
424 better public debates and policies. Partly, this is a limitation of our study, which focused on scientists
425 rather than on audiences. But also, as we show here, public input in climate policy is marginalized by
426 those scientists not perceiving the substantive value of public participation for policy making, drawing
427 a boundary between what is public communication and what is policy; a view that has been suggested
428 to be linked to political authority in policy-making (Entradas, 2016). More should be done to draw
429 climate scientists’ attention to the importance of public participation in research and policy, and to

430 reflect on social impacts of their communication, which could be reflected on training directed at
431 climate scientists – this should aim at awareness on the importance of dialogical approaches to engage
432 the public in the climate debate, to communicate uncertainty and risks of climate change to a reluctant
433 public to accept the anthropogenic causes of climate change (Weber and Stern, 2011; Roser-Renouf,
434 2016; Kahan, 2012) and to value public communication opportunities to engage and pursue the public
435 to act.

436 Secondly, we show the importance of (P) and (S) to scientists' engagement for this
437 community. Yet, similar to previous studies, we show that personal factors explain only a part of the
438 variance in engagement meaning that other important factors are at stake (Socio-demographics
439 explained 6%; perceptions alone accounted for 17%, and motivations accounted for 26% of the
440 variance). Importantly, our data suggest that while some factors seem to be important drivers amongst
441 scientists from different disciplines, others may be specific to scientific communities as we show here
442 by the importance of political orientations and awareness of controversy for climate scientists. It is
443 important that detailed studies of scientific communities are conducted to better understand and
444 address needs of particular communities. Hitherto, outreach across the sciences has been the main
445 focus of research; over the near future we need to compare the outreach in different scientific
446 communities in greater detail. What is at stake in this mobilisation effort was traditionally the
447 reputation of science, but increasingly it is the reputation of specific communities of science that take
448 precedence; this might entail competition for public goodwill among different sectors of science.

449 Thirdly, our research disentangles the contribution of intrinsic motivation to participation,
450 over and above the other factors with the public. Nevertheless, one could argue that social desirability
451 bias could artificially suppress the effect of external motivations as a scientist may be more inclined to
452 report an altruistic motivation than one that is driven by prizes. But the fact that enjoyment is a
453 common factor in other studies of scientists seems to leave little reason to believe that this should not
454 be the case. Future research should examine the social contexts and individual differences that support
455 autonomy and satisfaction, and what is required to protect intrinsic motivation, to prevent it being
456 crowded out by extrinsic rewards, which are the least autonomous form of extrinsic motivation (Deci
457 and Ryan, 1985). This has implications for scientific institutions that are to implement more strategic

458 approaches to scientists' public engagement with the building of normative and reward structures,
459 which could crowd out scientists' existing intrinsic motivations for engaging with the public, a shift
460 that could have more cost than benefit.

461

462 **Limitations**

463 As noted above, an inherent limitation of this study is the focus on scientists – the supply side. Our study
464 does not claim to address the demand side – audience reactions, motivations, behaviours, etc. More
465 directly, another inherent limitation of this study is the risk of non-response bias by those predisposed
466 to engage with the public given that respondents were self-selected. To minimize this, when collecting
467 the data, we explicitly invited 'non-communicators' to participate saying that the study was aimed at
468 both communicators and non-communicators. We cannot however conclude that the relative numbers
469 of communicators to non-communicators represent the ratio in this community as we do not know the
470 distribution in the population. But representative studies with a focus on funded scientists across
471 disciplines and of the climate scientific community in other countries (only 16% of German climate
472 scientists had no contact with public audiences, Ivanova et al., 2013), show that most scientists do
473 something, few are very active. The percentage of non-communicators in our study is similar to these.
474 We have no reason to think that the distribution of activity would be different across our sample. Our
475 response rate is acceptable when compared to response rates of similar online surveys of scientists or
476 surveys of other scholars including economists, lawyers or engineers (Schützenmeister and Bußmann,
477 2009). With a few exceptions, most previous surveys of scientists' engagement have relied on small,
478 and/or convenient samples, while larger-scale national surveys have usually combined scientists from
479 various disciplines (e.g. Royal Society, 2006, Pew surveys of scientists). Also, our *n* considers only
480 scientists from the same field of research. Similar surveys include Dudo, Kahlor, Abighannam, Lazard,
481 & Liang (2014) which surveyed 240 US nanoscientists (response rate of 25%), Besley, Dudo, &
482 Storksdieck (2015) and Dudo & Besley (2016) based conclusions on a 9% and 8% (respectively)
483 response rate of AAAS members. While not inferential, our findings provide indications on factors that
484 drive climate scientists engagement; and more broadly, communities involved in controversial topics.
485 We believe it is unlikely that the relationships investigated in our sample would become insignificant in

486 a larger sample or with members from different organisations/associations. Overall, we believe the
487 strengths of our sample much outweigh its limitations.

488

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491

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643

644 **Author contributions statements**

645 ME designed the study and wrote the paper; MB provided inputs and feedback into the paper and
646 conceptual advice. BL supported data collection in the US and provided feedback into the paper. ME
647 and JM conducted the data analysis and JM compiled the presentation of the data.

648

ⁱ This expression derives from Lewin's (1936 and 1951) original equation $B = f(S)$ where behaviour is a function of the total situation (S), i.e. all potential factors attributable either to the person (P) or the environment (E), expressed as $B = f(P, E)$. In our framework, this becomes a linear combination of two different sets of observed predictor variables.

ⁱⁱ Our research cannot conclude to whether these participatory events were attended by members of the public and if so, what the impact on policy of that involvement was.

ⁱⁱⁱ Media contact is given by counts of activities involving the media including interviews for newspapers, radio and TV, press releases and articles for magazines and newspapers, by number of active researchers.