Academic research into climate change is driven by humanity’s pressing concerns about environmental, health, technological and societal issues (Harris, 2011). Scientific outreach, the effective communication of this research, is increasingly important (Maddrell, 2010; Brewer and Ley, 2013) and is driven by mandates by research councils (Warren and others, 2007; Royal Society, 2008; NERC, 2011; Smith and others, 2013), a desire to broaden the impact of scientists’ findings or to make research accessible to policy makers (Oppenheimer, 2011). Increasing numbers of researchers are participating in public engagement (Peters and others, 2008a,b; McComas and others, 2009), providing rich context and content, while expanding to new regions and populations.

Increasing internet use, however, offers new opportunities for science communication. For example, in the United States, the internet is pervasive, with 87% of American online adults using it to research scientific topics (Horrigan, 2006). Some 60% of American adults cite the internet as their primary source of information (National Science Board, 2012). Online digital media, including websites, weblogs (blogs), micro-blogging services such as Twitter, podcasts, infographics and other artwork, YouTube videos and other outlets, may all be utilized for science outreach (Ashlin and Ladle, 2006), although each is not without its own specific challenges (Table 1).

Because of this pervasive internet use, particularly in the developed world, a growing number of scientists are using digital media to engage directly with non-scientists, share information and opportunities, promote their research, build networks and forge new links and collaborations (Butler, 2005; Bonetta, 2009; Fox, 2012; Xin and others, 2012; Darling and others, 2013). Further, well-established and reputable online sources can play a role in expanding access to scientific information, particularly as wireless broadband expands to new regions and populations.

The benefits of digital media are that it can deliver almost instant science commentary (Bonetta, 2007) and fill gaps in traditional science journalism (Wilkins, 2008; Bubela and others, 2009), providing rich context and content, while drawing parallels with and referencing and linking to other

### Table 1. Common challenges and mitigations for scientists engaging in online science communication (Peters and others, 2008a; Besley and Tanner, 2011; Harris, 2011; Somerville and Hassol, 2011; Bik and Goldstein, 2013; Darling and others, 2013; Smith and others, 2013; Stewart and Nield, 2013)

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Mitigations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited career credit given for publicizing work</td>
<td>Communication of research results increases the impact of publications. Publicly funded science should be widely available to the general public. Academic institutions and tenure committees should reward time and effort devoted to outreach.</td>
</tr>
<tr>
<td>Fear of misrepresentation by journalists; journalistic reports are too simple or brief</td>
<td>Scientists should endeavour to work with journalists, developing good communication skills and an understanding of journalistic process.</td>
</tr>
<tr>
<td>Insufficient time to develop a blog or website or wider outreach efforts</td>
<td>Range of options available, from guest blogging, to tweeting, curation of existing media or editing Wikipedia. Join community outreach efforts.</td>
</tr>
<tr>
<td>Fear of attack from sceptics or denials</td>
<td>As a scientist, it is vital to be able to defend your work and research. This is an important skill for young researchers to develop. Refer to robust, peer-reviewed research wherever possible. Make considered statements and posts.</td>
</tr>
<tr>
<td>Criticism from peers for not spending enough time on teaching or research; poor career credit</td>
<td>Outreach and blogging is increasingly seen as a useful skill and a vital part of publicly funded research, but it should not take the place of academic scholarship. Joining a thriving online community is an excellent way to build attention and support. Check institutional regulations and work with press and communications officers and funding agencies beforehand.</td>
</tr>
<tr>
<td>Fear of being unsuccessful or ignored</td>
<td>Be willing to correct a mistake if it is pointed out – just as you would in other work. Encourage commenting and discussion on posts.</td>
</tr>
<tr>
<td>Fear of breaking institutional rules or norms</td>
<td>Thoroughly research intended audience and start with a well-thought-out outreach strategy.</td>
</tr>
<tr>
<td>Fear of posting incorrect content, which is not peer-reviewed</td>
<td>Writing and communication skills only develop through practice. Read up on the wider literature on communication skills, and request university or departmental courses in science communication skills.</td>
</tr>
<tr>
<td>Not making a difference or not being able to reach the general public</td>
<td></td>
</tr>
<tr>
<td>Not being very good at wider communication and engagement</td>
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</table>
recent findings (Wilkins, 2008). Among the most popular
digital media are websites, blogs and micro-blogging
services such as Twitter. We note that they each have
different purposes and functions: Websites (where informa-
tion is arranged topically) may be better as an educational
resource, whereas blogs (where information is arranged
chronologically) are often more reactive, with posts about
new research and publications (Goldstein, 2009). Websites
can encourage dialogue through comments, contact forms,
discussion forums and embedded blogs. Blogs are more
likely to have two-way dialogue through commenting than
websites, and tend to build a community of regular visitors.
Twitter encourages the most direct and immediate form
of engagement.

There are a number of criticisms of the use of digital
media as a tool for science communication, including that it
generally only reaches a few already knowledgeable science
enthusiasts and professionals (Bubela and others, 2009;
Kouper, 2010). Indeed, internet use correlates with income,
gender, education and location; people using the internet for
research are likely to be affluent and relatively well
educated (e.g. Flores, 2003, from research in Chile). Critical
evaluation of the effectiveness of digital media in science
communication is rare (Shema and others, 2012). Blogs and
websites may also reinforce the knowledge-deficit model of
science communication (Bubela and others, 2009). Kouper
(2010) found that blogs and websites rarely provide the
extensive critique or articulation on controversial issues that
they may claim. Finally, websites and blogs are time-
expensive, require skill and research and may provide
academics with limited career credit (Table 1).

Here we evaluate www.AntarcticGlaciers.org, a website
with an embedded blog and Twitter feed, established to
communicate peer-reviewed science to the general public.
We collect together relevant science communication
literature and outline the rationale and objectives of the
website, before evaluating the degree to which these goals
have been achieved 18 months after the website's launch.
We conclude with a discussion and recommendations for
other practitioners of online research communication
and outreach.

RATIONALE AND OBJECTIVES

We developed www.AntarcticGlaciers.org in July 2012 to
communicate our science and research. The rationale was
that glaciers, ice sheets and their dynamic response to
environmental changes are frequently poorly understood by
the population at large (Hambrey and others, 2010; Francek,
2013), and there is a lack of informative websites available
to the interested public. The goal of AntarcticGlaciers.org
was therefore to communicate key scientific concepts and to
deliver new research findings and scientific articles to the
public and to other academics. Our objectives were:
(1) to clearly explain and illustrate key concepts in
glaciology as well as the latest scientific developments in
Antarctic research, from our own and others' research; (2)
to provide information well aligned with undergraduate and
school national curriculums, supporting university and
school learning; and (3) to include interactive features and
social networking tools to encourage user engagement and
discourse.

The intended audience for AntarcticGlaciers.org is broad,
including school students (16–18-year-olds), interested
adults, university students and other academics. A focus

Davies and Glasser: Correspondence
EVALUATION

Eighteen months after launch (1 July 2012 to 31 December 2013), AntarcticGlaciers.org had become highly visible on Google, and the number of Twitter followers had reached 1415. Over 1000 unique visitors landed on the website per week, and as of 31 December 2013 it had received >73 000 visitors (>57 000 unique visitors) and >150 000 page views (Fig. 2a). 22.3% of the hits are by returning visitors. There were visitors from every continent. The website is well targeted for certain search engine optimization (SEO) terms, resulting in increasing traffic from organic searches (Fig. 2b), while direct traffic contributes only a fairly static 1000 visitors per month. AntarcticGlaciers.org has received incoming links from several other websites, including high-profile university websites, and as a result the homepage has a Google PageRank of 4. To date, 60% of visitors have found the website by searching through Google, 11.9% through a referral and 15.9% from direct traffic (Fig. 2c; cf. Table 2).

To ensure that the website was meeting the needs of its users, an anonymous feedback survey was initiated; there were 44 respondents. This survey was initiated throughout the site lifetime. There were equal numbers of male and female respondents, with the largest subset being in the 22–35-year-old age bracket (50%; Table 3). The majority of survey respondents gave their occupation as ‘At university’ (Table 4). It has proven difficult to obtain feedback from school (UK Advanced-level (A-level)) students. We note that although A-level students may be looking at the website, they have little incentive to complete the survey, whereas teachers and researchers have more reason to support the website. The reasons given for looking at the website included general interest (75.0%), to help with their studies (28.1%) and because they were a researcher in a related field (31.3%). Academics made up 26% of the website’s visitors (Table 4), which supports our ‘dissemination of scientific articles’ goal.

When asked what they liked about the website, respondents primarily referenced the easy navigation and well-organized site structure, the site’s informative nature, photographs and maps, the accessible language, the simple and thorough science themes, and the fact that it had an upbeat approach and was less ‘serious’ than other, similar sites (Fig. 2c). Respondents consistently cited the blog, fieldwork diaries and photographs as their favourite part of the website, with the specific ‘Students’ and ‘Careers’ sections coming in second. The most popular posts are the more general blog posts about careers and study strategies. This supports the findings of Bonetta (2007), who stated that the most popular blogs do not write only about science.

Suggestions for improvements received in the survey included more, and larger, photographs, especially in the glossary, more maps and diagrams, increasing links both within-site and to external sites, more content and science pages, and more ‘human interest’, such as the day-to-day life of a researcher, fieldwork diaries and interviews (Fig. 2d).

Analysis of the short biographies of the 1415 followers of the AntarcticGlaciers.org Twitter feed (@AntarcticGlacie) 18 months after launch (Fig. 2f) showed that although a large portion of Twitter followers self-identified as postgraduate geosciences students (153 people; 10.8%) or academics with a professional interest in Antarctic glaciology (131 people; 9.3%), the Twitter feed is also followed by a high number of non-scientists with no professional interest in glaciology (448 people; 31.7%). It is also followed by 68 undergraduate students (4.8%), 34 teachers or school departments (2.4%), 94 journalists, science writers or communicators (6.6%), and 100 outreach organizations or charities (7.1%). Twitter is therefore useful for publicizing our website and research to schoolteachers, journalists and academics from other disciplines. This distribution of followers is not dissimilar to that recently found for marine scientists (Darling and others, 2013) and demonstrates that the Twitter feed is useful for reaching people beyond the academic sphere.
Fig. 2. Analysis of visitors to AntarcticGlaciers.org (see Table 2 for definition of terms). (a) Unique visitors and page views, as determined over 18 months from website launch by Google Analytics. (b) Sources of traffic through time to the website (number of visitors per month). All traffic is unpaid (i.e. there was no paid advertising). (c) Sources of traffic to AntarcticGlaciers.org over the first 18 months. Search traffic includes people using Google, Yahoo or other search engines. Referral traffic includes people who have followed a link from another website. Direct traffic includes people who have typed in the URL directly. (d) Results of web-based survey, indicating the most common answers people gave in a free-text answer when asked what they liked about the website. (e) Results of web-based survey, indicating the most common answers people gave in a free-text answer when asked how the website could be improved. (f) Analysis of followers to @AntarcticGlacie on Twitter, using self-identification given in the ‘bios’ on followers Twitter pages. Raw numbers are given in parentheses.
Overall, we found that AntarcticGlaciers.org has had some success at publicizing the research of the authors (observed through, for example, Twitter retweets, referrals, and anecdotal evidence), as well as broader concepts and ideas concerned with glaciers and climate. It is increasing in popularity and receives steadily more visitors (Fig. 2). For example, search traffic went from 140 visitors in July 2012 to a maximum (as of date of writing) of 4868 in November 2013. In May 2013, monthly unique visitors surpassed 4000 for the first time. The large proportion of organic search traffic received by the site ensures that it is easily accessible and easily found by members of the public, helping us to reach our target audience. These data show that the advantages of using social media, websites and blogs for science communication are many (Table 5). Online science communication can reach a broad spectrum of society and bring research to the attention of journalists and science writers, who command larger audiences. AntarcticGlaciers.org provides a useful information resource that can supplement more direct public engagement, and our interactive website features and social media (e.g. Twitter) help to increase dialogue. We found that AntarcticGlaciers.org began to become effective within a relatively short time, but for optimum success, websites and blogs should be viewed as long-term, ongoing endeavours that will outlast specific research projects. Finally, our website and blog supports university and school pedagogy, by increasing the breadth and depth of knowledge of the lecturer, and by providing a supportive resource for schoolteachers and undergraduate and postgraduate students (Table 5).

Table 3. Age of respondents of survey

<table>
<thead>
<tr>
<th>Age bracket</th>
<th>Percentage of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 16</td>
<td>0%</td>
</tr>
<tr>
<td>17–18</td>
<td>0%</td>
</tr>
<tr>
<td>19–22</td>
<td>18.18%</td>
</tr>
<tr>
<td>23–35</td>
<td>50%</td>
</tr>
<tr>
<td>36–65</td>
<td>27.27%</td>
</tr>
<tr>
<td>Over 65</td>
<td>2.27%</td>
</tr>
<tr>
<td>Prefer not to say</td>
<td>2.27%</td>
</tr>
</tbody>
</table>

Table 4. Occupation of respondents

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Percentage of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>At school or college</td>
<td>0%</td>
</tr>
<tr>
<td>At university</td>
<td>41.86%</td>
</tr>
<tr>
<td>In other full-time education</td>
<td>22.33%</td>
</tr>
<tr>
<td>Scientist/researcher/academic</td>
<td>25.58%</td>
</tr>
<tr>
<td>Teacher</td>
<td>6.98%</td>
</tr>
<tr>
<td>Other full-time employment</td>
<td>18.6%</td>
</tr>
<tr>
<td>Not working</td>
<td>4.65%</td>
</tr>
<tr>
<td>Retired</td>
<td>4.65%</td>
</tr>
</tbody>
</table>
Our evaluation shows that only 18 months after launch, the website is a useful resource, with some aspects that do challenge the deficit-knowledge model, with interactive features and a good understanding of the audience. It is a good supplementary tool to any outreach endeavour that seeks active dialogue with an audience. It reaches a broad spectrum of the population, including other academics, journalists, teachers, university students and the broader public. However, direct public dialogue is limited in depth and detail, so the outreach endeavour must be supported by other, more direct public engagement. In general, we find that creating a research outreach website or blog without careful consideration and thought can result in a largely ineffective tool. Without careful audience targeting and engagement, online tools for science communication may reinforce simple knowledge-deficit models (Table 5) and are at risk of being read by only a small number of science enthusiasts (Kouper, 2010). Researchers must invest time in SEO in order to be visible on Google. Finally, excellence in online science communication is a strong time-sink that requires ongoing commitment (Bik and Goldstein, 2013).

Together with the existing literature, our feedback survey and our website analysis, we can provide recommendations for excellence in outreach websites and blogs. Among the advantages of websites and blogs are that they can be quickly and cheaply set up using a number of pre-built platforms (e.g. Wordpress), which provide a professional layout and a simple content-management scheme. Careful SEO and targeting of the site’s content to a specific audience helps academic blogs and websites avoid being lost in the blogosphere and can increase the number of hits. Installing a tool such as Google Analytics will allow tracking and analysis of the website and aid website evaluation. Identification of a website author, linked to a Google Plus profile, places your name and a headshot beside the page in the search results. People are more likely to click on pages with a headshot photograph. Google Authorship may, in the future, result in improved ‘author rank’ for highly rated authors, which may improve placement on Google search pages (Table 2).

A thematically organized website aids navigation and helps readers find the information they want. Using blogs on their own may be problematic for education and science communication, as it is difficult for users to explicitly find subjects they are interested in (Goldstein, 2009). However, like other embedded blogs (cf. Wilkins, 2008; Nisbet and Scheufele, 2009; Somerville and Hassol, 2011; Stewart and Nield, 2013), the AntarcticGlaciers.org blog provides more ‘human interest’ and is more reactive, commenting on recent news or publications. Our feedback survey highlighted the need for personal stories, photographs, narrative and emphasis on academic life, and we therefore encourage the dissemination of fieldwork, lab diaries or other forms of narrative. Without infringing copyright, both websites and blogs should make effective use of high-quality images as ‘hooks’, drawing people into the website (Miller, 1986).

An effective digital media strategy must carefully identify the intended audience and analyse their needs, and, crucially, their scientific understanding (Smith and others, 2013). Ideally, practitioners should meet their intended audience, perhaps by holding focus groups, engaging with school curricula or interacting with professional groups or societies. Our focus group meetings emphasized the need for careers and study advice, for clear pointers on relevance to the UK National Curriculum, and for an easy-to-navigate website structure. Reviews of the audience, through feedback surveys, Twitter and Google Analytics, can aid audience understanding and targeting. Our ability to respond to audience feedback has been crucial in providing a website that meets the needs of its readers.

Finally, websites and blogs can be a community effort, but authors need to have ownership, otherwise the attempt will fail. Institutions can support their staff and students’ blogging efforts, for example, by providing free hosting, access to communications or website development training (Warren and others, 2007; Harris, 2011; Stewart and Nield, 2013), promotion of and links to blogs on university websites (Batts and others, 2008), career incentives to undertake excellence in outreach (Royal Society, 2008), funding (including of public events), and by providing press office support and online promotion. Academics can supplement training courses in science blogging by reading examples of best practice in public engagement by other scientists, journalists and bloggers.

Online science communication has numerous benefits for the researcher. For example, writing about new articles or topics requires a deeper understanding of the literature, which may often be outside the researcher’s normal realm.
CONCLUSION

We conclude that AntarcticGlaciers.org has been successful in communicating science to a wide public, although a high proportion of visitors and Twitter followers are scientists with a professional interest in Antarctic glaciology. We have had limited success in reaching school students. Some aspects do reinforce the top-down knowledge-deficit model, and this is limited by trying to encourage interaction and relationships, for publicizing new posts and for reaching out to journalists, schoolteachers, other academics and the broader public. Search engine optimization is essential to build traffic. Using personal narrative and photographs was crucial to generate interest and engage readers of the AntarcticGlaciers.org website. We recommend the use of websites and blogs to other academics wishing to engage in public communication of science as a low-budget but time-intensive strategy.

In summary, a successful online outreach strategy must fulfill the following criteria: (1) identify and clearly understand the intended audience and their needs, and have the ability to evolve in response to the audience; (2) good search engine optimization is essential to build an audience; (3) the text should be easy to understand and illustrated with a strong narrative, human interest and plenty of photographs, with a small number of key details that are relevant to the audience; (4) the online strategy should encourage and allow engagement, conversations and direct interaction.

ACKNOWLEDGEMENTS

AntarcticGlaciers.org was supported and funded by the Quaternary Research Association (QRA) and the Scientific Committee for Antarctic Research (SCAR). It was developed and is maintained by www.Senktec.com, a website development company, who provide ongoing support. While the QRA supports this initiative, the views expressed are those of the authors and do not necessarily represent those of the QRA. This analysis was conducted while B.J.D. was a recipient of a SCAR Fellowship award and was visiting the Antarctic Research Centre, Victoria University of Wellington, New Zealand. B.J.D. was also funded by a UK Natural Environment Research Council grant through the Antarctic Funding Initiative (grant AF1 9-01; NE/F012942/1) awarded to N.F.G. We thank Rhian Salmon and Heidi Roop for constructive comments. We also thank two anonymous reviewers for thoughtful and constructive comments.

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15 February 2014

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(Bonetta, 2007). Literature must also be read while it is fresh new; the article needs to be written in a timely manner to be relevant. Writing articles in an easy-to-read, accessible format will help develop writing skills. Website authors and bloggers will gain a deeper understanding of the internet, programming and search engine optimization, all of which have practical uses in an academic career, and may even open up different career options. Bloggers are more aware of online resources, which may help develop innovative teaching resources. Figures, maps and conceptual diagrams are easily translated into lecture slides, and vice versa; indeed, blogging and teaching are mutually beneficial since science communication and pedagogy share many of the same skills, both being based in effective communication.

Using digital media professionally can increase the visibility and online presence of an early-career researcher, opening them to new collaborations and networks, and making them more visible to future employers. Blogging and tweeting about journal publications can increase their prominence and citations (Bik and Goldstein, 2013; Darling and others, 2013). Writing short summaries of published journal articles means that they are close to open access, with lay readers able to access the key findings of the work in simple, understandable language. Some writers use blogs to develop ideas and foster collaboration prior to submitting work to peer review (Fox, 2012).


