1 Exploring TikTok as a promising platform for geoscience

2 communication

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8 Abstract. With TikTok emerging as one of the most popular social media platforms, there is significant potential for science 9 communicators to capitalize on this success and share their science with a broad, engaged audience. While videos of chemistry 10 and physics experiments are prominent among educational science content on TikTok, videos related to the geosciences are 11 comparatively lacking, as is an analysis of what types of geoscience videos perform well on TikTok. To increase the visibility 12 of the geosciences and geophysics on TikTok and to determine best strategies for geoscience communication on the app, we created a TikTok account called "Terra Explore" (@TerraExplore). The Terra Explore account is a joint effort between science 13 14 communication specialists at UNAVCO, IRIS (Incorporated Research Institutions for Seismology), and OpenTopography. We 15 produced 48 educational geoscience videos over a four-month period between October 2021 and February 2022. We evaluated 16 the performance of each video based on its reach, engagement, and average view duration to determine the qualities of a 17 successful video. Our video topics primarily focused on seismology, earthquakes, topography, lidar (light detection and 18 ranging), and GPS (Global Positioning System), in alignment with our organizational missions. Over this time period, our 19 videos garnered over 2 million total views, and our account gained over 12,000 followers. The videos that received the most 20 views received nearly all (~97%) of their views from the For You page, TikTok's algorithmic recommendation feed. We found 21 that short videos (< 30 s) had a high average view duration, but longer videos (>60 s) had the highest engagement rates. 22 Lecture-style videos that were approximately 60 seconds in length had more success in both reach and engagement. Our videos 23 that received the highest number of views featured content that was related to a recent newsworthy event (e.g., an earthquake) 24 or explained location-based geology of a recognizable area. Our results highlight the algorithm-driven nature of TikTok, which 25 results in a low barrier to entry and success for new science communication creators.

26 1 Introduction

Given the current popularity and ubiquity of various social media platforms, scientists have a unique opportunity to directly interface with a diverse public audience. Not only can scientists use social media to improve the public perception of science, but they can also work to combat the growing tide of scientific misunderstanding and misinformation (Hilary and Dumebi, 2021; Shu et al., 2020). Over the last decade, scientists have found success using social media, especially Twitter, to share scientific discoveries (Côté & Darling, 2018; Schmitt, & Jäschke, 2017; Smith, 2015) and affect social change (Jahng & Lee, 2018). However, the social media landscape is frequently changing, and scientists must adapt to new changes and trends to effectively reach an audience.

Over the past two years, TikTok has dominated the social media landscape and currently boasts over one billion monthly active users (TikTok, 2021a). On TikTok, users create and interact with short-form video content (~15 seconds to 3 minutes). TikTok is especially popular among a younger demographic, with 25% of users in the U.S. being under the age of 19 (Statista, 2022a). With the growing popularity of TikTok among users of all ages, TikTok presents an excellent opportunity to strategically examine how scientists can use social media to broaden their reach and create a more scientifically literate public. On TikTok, science communication is highly personalized, as science practitioners are presented in an approachable and relatable way (Zeng et al., 2020).

41 Of the STEM (science, technology, engineering, and mathematics) disciplines, the geosciences are especially 42 relatable; essentially everyone has personal experience with geoscience-related information in their daily lives. Effective 43 communication of geoscience topics is important because the geosciences are intrinsically linked to the human and natural 44 world, and it is beneficial for everyone in society to understand the basics of geoscience. Increased awareness and 45 understanding of geohazards like earthquakes, landslides, floods, and global climate change can help to improve personal 46 safety and increase support for public policy. Additionally, geohazards are often the subject of considerable misinformation— 47 persistent rumors that Yellowstone is about to catastrophically erupt serves as a frequent example—so providing high-quality, 48 scientifically accurate information is especially important.

49 Recognizing the substantial potential for geoscience communication on TikTok, we created a TikTok account called 50 "Terra Explore" (@TerraExplore) to share educational geoscience and geophysics videos. With these videos, we sought to not 51 only enhance the visibility of geoscience and geophysics on TikTok but also to assess the best strategies for science 52 communication on the platform and evaluate what factors may impact how well a video performs on the app. We analyzed the 53 reach (how many individuals saw the video), the engagement (the number of interactions with the content, e.g., "likes" or 54 "comments"), and the average view duration of each video we posted to determine the qualities of a successful educational 55 geoscience TikTok video. The longer that someone watches a video and the more engagement the video receives demonstrates 56 interest in the video and the impact of the science communication, which will likely be rewarded within the algorithm with 57 expanded video reach. Through this work, we are able to determine the factors of a video that help maximize the reach and 58 potential for geoscience communication on TikTok.

59 2 Basics of TikTok

60 TikTok is a short form video app that allows users to create videos using music, filters, text, and camera effects on 61 their mobile phones. The app is free to download on Apple and Google Play stores. While TikTok videos were originally all 62 less than a minute long, TikTok increased the upper limit to three minutes during late summer of 2021 (Kirchhoff, 2021). 63 There is now also the limited ability to upload a single 10-minute video file from your device to TikTok. The COVID-19 64 global pandemic served as a catalyst for the growth and success of TikTok among different demographics (Feldkamp, 2021). 65 During the first quarter of 2020, TikTok had more than 315 million installs across the Apple and Google Play app stores, which 66 was the most downloads ever for an app in a single quarter (Briskman, 2020). This was a significant increase from the 219 67 million installs during the fourth quarter of 2019 (Statista, 2022b). During the first quarter of 2022, TikTok was the most 68 downloaded app worldwide (Sensor Tower, 2022).

69 TikTok provides two primary feeds on which a user can watch content: Following and For You. Upon opening the 70 app, videos immediately begin playing on the For You page. Users can toggle between the two feeds at the top of the screen. 71 TikTok uses AI algorithmic recommendations to determine what videos are shown on a user's For You page, which are often 72 based on the user's profile settings, their location, and their activity on the app (Smith, 2021). In order to help users discover 73 new content categories and creators, as well as to avoid a repetitive experience, TikTok also provides diverse recommendations 74 on the For You page (TikTok, 2020). The For You page is notable and unique amongst social media feeds, as videos with 75 extremely few views (~ 10 views) can be recommended, thus guaranteeing a potential audience for every post regardless of the 76 number of account followers. Based on TikTok's internal data, 69% of a user's time on the app is spent on the For You page 77 (Stokel-Walker, 2020), making it the primary way users view and discover new content. Only videos from accounts that 78 someone follows are shown on the *Following* feed, although these videos may also be shown on the *For You* page. Videos 79 additionally can be viewed on a creator's profile page or by searching video hashtags or sounds. While TikTok does not 80 publicly disclose any information regarding how their AI recommendation algorithm functions, independent data analysis of 81 trending videos on TikTok found that a higher level of video engagement through likes, comments, and shares leads to a higher 82 chance of the algorithm showing the video to more people via the *For You* page (Klug et al., 2021).

83 **3 Educational landscape on TikTok**

Despite the common perception that TikTok is a "dance app" for kids, there is an abundance of educational content on the app that is widely consumed. Research shows that youths agree that TikTok serves as a window for online learning and aids in educational development (Azman et al., 2021). This positive educational potential led TikTok to be integrated into various aspects of instruction in higher education (Draganić et al., 2021; Escamilla-Fajardo et al., 2021; Radin and Light, 2022). As well, studies show that TikTok allows non-expert users to participate in scientific discussions—such as those related to climate change—that oftentimes only take place among expert-level scientists and journalists (Basch et al., 2022; Hautea et al., 2021).

91 The TikTok leadership has also worked to strengthen and promote educational content on the app. In May of 2020, 92 TikTok launched their "#LearnOnTikTok" campaign, where they partnered with 800 public figures, educational institutions, 93 and professional experts to bring learning material to TikTok (Thoensen, 2020). These partnerships included notable science 94 communicators such as Bill Nye and Neil deGrasse Tyson. While the campaign partnered with specific creators, anyone on 95 TikTok can create videos and use the #LearnOnTikTok hashtag. As of February 2022, videos using the "LearnOnTikTok" 96 hashtag have a collective 240.4 billion views. The success of the #LearnOnTikTok campaign demonstrates the desire for 97 consumption of educational material on the platform and provides an ideal opportunity for science communicators to capitalize 98 on a platform with a large user base. By leveraging this already well-known and popular hashtag, geoscientists can promote 99 their content to a receptive audience, potentially increasing knowledge of and interest in geoscience topics.

100 The manner in which science content is presented on TikTok—lecture style vs. demonstration—influences user 101 engagement. Habibi and Salim (2021) evaluated the engagement of lecture-style and experimental educational science videos 102 from one account on TikTok, largely related to biology, and found that scientific experiments presented in dynamic ways 103 received the most engagement. Hayes et al. (2020) observed that TikTok videos of at-home chemistry experiments can increase 104 knowledge of and interest in chemistry for viewers. In addition to videos showing chemistry experiments, Hight et al. (2021) 105 found that students enjoyed creating and consuming content on TikTok that featured anthropomorphized chemistry concepts. 106 Based on an analysis of memetic science content on TikTok, Zeng et al. (2020) found that the presence of science on TikTok 107 is dominated by chemistry and physics experiments.

108 Thus far, the geosciences have been excluded from evaluations of science content and science communication on 109 TikTok. Much of geoscience-related content on TikTok is created by young individuals who have recently or are currently 110 completing undergraduate or graduate degrees in the geosciences. Videos typically feature geology-related "memes" or jokes, 111 showing what's inside a rock when you break it open, or explaining geoscience topics. Content related to geology and 112 geophysics on TikTok has significantly fewer views than content related to physics, biology, and chemistry (**Table 1**). Unlike 113 chemistry and physics, the geosciences do not as easily lend themselves to at-home experiment-based content, but do allow 114 for unique, hands-on demonstrations as well as the potential for "field trip" style presentations. Additionally, geoscience is a 115 discipline that every person has had some level of interaction with (soil, geohazards, GPS on their phone, etc.). Our aim was 116 to not only enhance the visibility of geoscience and geophysics content on TikTok but also to determine and evaluate the best 117 strategies for geoscience communication on TikTok.

Hashtag	View Count
#physics	3.3 billion
#biology	3.2 billion
#chemistry	3.0 billion
#geology	617.6 million

#geophysics 2.7 million

Table 1. Number of total video views on TikTok for different science-related hashtags, as of October 2021 before our project began.
 Within the app, TikTok denotes the total number of video views per hashtag.

121 4 Account and video creation

122 In October 2021, we created an account "Terra Explore" to evaluate the potential of TikTok for geoscience 123 communication (Fig. 1a). Between 10/8/2021 and 2/6/2022, we published 48 videos. The "Terra Explore" name is a nod to 124 the many ways scientists explore Earth (Terra) using geoscience tools and techniques. The Terra Explore account is a joint 125 effort led by science communication specialists from UNAVCO, IRIS (Incorporated Research Institutions for Seismology), 126 and OpenTopography. UNAVCO and IRIS are non-profit university-governed consortiums that operate the GAGE and SAGE 127 facilities (respectively) on behalf of the National Science Foundation (NSF), serving the geophysics community. 128 OpenTopography is co-managed by the San Diego Supercomputer Center at the University of California San Diego. 129 UNAVCO, and Arizona State University and facilitates community access to high-resolution, Earth-science-oriented 130 topography data and related tools and resources, also on behalf of NSF.

131 Our primary aim with the Terra Explore account was to determine the best strategies for geoscience communication 132 on TikTok and increase the presence of geoscience and geophysics content, ideally targeting users aged 19-and-under and 133 female/girl users. Our videos featured three rotating front-facing hosts and were typically done in a "lecture-style" format, 134 where the host talks directly to the audience explaining a geoscience topic while using engaging background visuals. Two of 135 the hosts are female and presented the majority of the videos, and one is male. We primarily used TikTok's "green screen" 136 feature to add visual imagery to videos, in addition to image and text overlays (Fig. 1b). TikToks were filmed in individual 137 home offices using simple equipment such as iPhone/Android devices, small lights, and low-cost lavalier microphones. We 138 used TikTok's built-in captioning feature to provide captions on all of our videos to increase their accessibility.

139 We largely produced content related to our organizations' missions. Video topics primarily focused on seismology, 140 earthquakes, topography, lidar (light detection and ranging), and GPS (Global Positioning System). We often used and 141 incorporated existing educational graphics and animations produced by IRIS and UNAVCO. The videos we produced ranged 142 between 9 seconds and 2 minutes 30 seconds in duration, with an average video duration of 57 seconds. Each video post 143 contained a short description and approximately five relevant hashtags. Due to staff time limitations, we did not set a specific 144 video posting schedule, but averaged between one to four videos posted per week, with the most videos posted during the first 145 two months of the project. A number of videos were cross-posted and promoted on UNAVCO, IRIS, and OpenTopography's 146 other social media accounts.

Our video content largely did not include TikTok "memes" or sounds. "Memes" are among the most common videos on TikTok and use viral audio clips that are transformed and applied to different visual imagery, capitalizing on popular culture or shared experiences. Given the educational aspect of our videos, we chose to follow a more traditional video format where the video host speaks directly to the audience as a teacher would to a classroom. The most common type of video we produced presented ground motion visualizations (GMV) for notable earthquakes magnitude 6 or higher (**Fig. 1c**). These GMV animations were already being produced by IRIS and disseminated through other social media channels. On the Terra Explore TikTok, the front-facing video host explains what is shown in the animation: earthquake waves pass across seismic stations in North America, and we can see representation of the ground moving up and down (although the movements are too small to feel). Videos were timely in that they were typically posted the day of or the day after the earthquake occurred. As the content and style of these GMV videos were largely identical, they provided a way to more clearly evaluate specific factors that may affect a video's performance.

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Figure 1. (a) Representative screenshot of the Terra Explore account. Our profile page has a Linktree that provides external links
 to the UNAVCO, IRIS, and OpenTopography websites. (b) Screenshot of typical video using the "green screen" effect. (c) Example
 screenshot of a GMV video.

163 **5 Methods**

We used TikTok's built-in account analytics to download and record video and account metrics for the period between 10/8/2021 and 2/6/2022 to evaluate the performance of each video and analyze what factors may impact the success of a video. With our analyses, we largely sought to evaluate the features of geoscience content that users watch the most and engage with the most on TikTok, as well as what may impact the performance of a video within the algorithm. (Does the length of a video matter? The time of day it is posted at? Etc.) We began collecting data upon video publication and continued until the end of the reporting period, ensuring that there was a minimum of two weeks of available data per video. We found that videos typically received the majority of views and engagement within the first week after publication, and thus this timeframe is generally sufficient to observe video trends.

We collected all of the summary data for each individual video that TikTok provides: video views, likes, comments, shares, total cumulative play time, average duration the video was watched, percentage of viewers who watched the full video, unique reached audience, the percentage of video views by section (*For You*, personal profile, *Following*, hashtags), and the percentage of views by region/country. Prior to August 2022, TikTok did not provide information on the gender or the age of users who view a video, although they now provide this information for videos created after that date.

177 We evaluated the videos based on reach and engagement metrics, as well as average video view duration. We used 178 metrics of reach (number of unique users the video was seen by) and engagement (likes, comments, and shares) to calculate 179 the engagement rate of each video. The engagement rate is calculated as the engagement parameter as a percentage of total 180 reach (e.g., Likes / Audience Reached *100). We hypothesize that the videos with the highest engagement rates and longest 181 view durations will receive the highest views and reach (Klug et al., 2021). Longer view duration indicates greater interest in 182 the video and subject, and engaging with the video through likes, comments, or shares demonstrates additional interest, 183 indicating that the science communication was successful and impactful. This interest and engagement with the video is likely 184 to be rewarded within the algorithm, with the video being shown to more people on the For You page.

We performed correlation analyses of variables related to views, engagement rate, and view duration to evaluate any trends in video performance. We calculated the Pearson correlation coefficient to determine the correlation between variables and calculated p values to determine the statistical significance of each relationship ($p \le 0.05$ is selected to indicate statistical significance). All individual plots and values from the correlation analyses are available in the Supplementary Materials.

We also recorded weekly account metrics including total video views, profile views, total account likes, total comments, total shares, total followers, new followers, gender of followers, and region/country of followers. TikTok reports gender as a binary percentage of male and female followers. Of these metrics, we most closely evaluated the gender percentage of followers over time to see how well we were able to reach specific demographics.

193 6 Results

194 **6.1 Video and account metrics**

During the four-month test period, the Terra Explore account gained over 12,000 followers, and the 48 videos published garnered 2,106,504 views, 3,579 comments, and 5,144 shares. The videos had a combined 22,297 hours of watch time. Individual video views ranged between 522 views and 684,100 views, with a median of approximately 2,400 views. Seven videos received over 90,000 views, and 30 videos received less than 3,000 views. Videos were uploaded at various times throughout the day, and the videos that received the most views (>90,000) were uploaded either in the morning or early afternoon Mountain Standard Time (MST) (UTC-7) (**Fig. 2**). However, there was no statistically significant correlation between video upload time and the number of video views (p > 0.05). We did not spread video publication evenly throughout the week, and the greatest number of videos were posted on Tuesdays. Videos that were published on Wednesdays and Thursdays received fewer views than other days of the week, with videos published on Mondays receiving the most cumulative views on average (**Fig. 3**).

205 Tables 2-3 record the topic and metrics of our ten most viewed and ten least viewed videos. Our highest viewed 206 video described an offset curb in Hayward, California that was famous among geologists for recording the continual slow 207 motion along the Hayward Fault (part of the San Andreas fault system). Three of our ten most viewed videos were GMVs, one 208 was a demonstration, and the rest were lecture-style videos. The lecture-style videos were either related to discussing a geologic 209 topic related to a specific location or a recent newsworthy event/anniversary. Our ten least viewed videos included five lecture-210 style videos, two demonstration videos, one in-person video, one miscellaneous video, and one meme-style video. These 211 lecture-style videos were all explainer videos of topics related to seismology or geodesy. Our least viewed videos were all 212 published in either October or November 2021 when we first began our account. However, our second and third most viewed 213 videos were also published during this timeframe. Our top ten most viewed videos averaged 67 seconds in length and had an 214 average video view duration of 58%, while our ten least viewed videos averaged 44 seconds in length and had an average 215 video view duration of 37%. The top ten most viewed videos had an average engagement rate of 11% for likes, while the ten 216 least viewed videos had an average engagement rate of 8% for likes.

Of the account's over 2.1 million video views, 95% of those views came from videos shown on the *For You* page. Nearly twice as many videos were viewed on the Terra Explore profile page than on the *Following* feed. Videos were rarely discovered by a user directly searching for a specific hashtag (**Table 4**). Our most viewed videos received nearly all (~97%) of their views from the *For You* page. Videos with fewer views were shown to fewer users on the *For You* page and received a higher percentage of views from the Terra Explore profile page or the *Following* feed (**Fig. 4**).

85% of the account's followers are located within the United States, followed by 3% from Canada. 84% of the total number of video views came from users located within the United States, with each individual video averaging 78% of its views from users in the United States. Canada was the second highest video viewer region on 22 videos, Australia on 17 videos, the United Kingdom on five, and the Philippines on four, with the secondary country yielding on average 5% of a video's views. As of February 2022, the Terra Explore account had 36.5% female and 63.5% male followers. This percentage remained relatively unchanged over the four-month duration of video posts.





Figure 2. Time of video upload in Mountain Standard Time (MST) (UTC-7) and the number of views the video received (on logarithmic scale). Videos that received >90,000 were uploaded in the morning or early afternoon MST (UTC-7). There is no statistically significant correlation between the time of video upload and the number of video views (p > 0.05).





Figure 3. (a) The number of videos uploaded per day of the week. (b) The average total number of video views received based on the day of video upload. Videos that were posted on Wednesdays and Thursday received the lowest number of views on average.

Video Topic	Date Published	Length (s)	Views	Likes (ER %)	Comments (ER %)	Shares (ER %)	Avg. % Watche d
Hayward, California offset curb (Hayward fault creep)	2/1/2022	108	684,10 0	104,600 (16)	1,209 (0.19)	2,332 (0.37)	51
GMV of M6.2 Hawaii earthquake	10/11/2021	30	372,30 0	43,900 (13)	558 (0.16)	1,066 (0.31)	85
Demonstrating earthquake magnitude with spaghetti	10/22/2021	34	305,50 0	24,300 (8)	444 (0.15)	346 (0.12)	78
GMV of M7.3 Indonesia earthquake	12/14/2021	56	184,60 0	14,000 (10)	205 (0.55)	344 (0.15)	60
Hollister, California fault creep and impact on infrastructure	2/6/2022	88	190,30 0	19,600 (11)	386 (0.22)	612 (0.34)	41
Wallace Creek (San Andreas Fault, California) stream offsets	12/27/2021	73	133,50 0	6,871 (5)	128 (0.10)	48 (0.04)	55
Lidar "x-ray vision" of Earth's surface (San Andreas Fault, California)	10/16/2021	48	92,900	5,859 (7)	105 (0.12)	49 (0.05)	56
Cascadia 1700 earthquake and tsunami anniversary	1/26/2022	147	21,600	1,861 (10)	83 (0.42)	71 (0.36)	43
GMV of Nicaragua M6.2 earthquake	11/9/2021	39	11,700	1,102 (10)	37 (0.34)	29 (0.26)	55
Using lidar to uncover ancient Mesoamerican complexes	10/30/2021	47	7,896	1,339 (17)	20 (0.26)	13 (0.17)	53

Table 2. Top ten most viewed videos between 10/8/2021 and 2/6/2022 on the Terra Explore and corresponding metrics. GMV = ground motion visualization, M# = earthquake magnitude. ER % = Engagement Rate (Metric / Audience Reached *100). All videos had an average video view duration of 40% or higher. These videos correspond with #1–10 in Fig. 4.

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Video Topic	Date Published	Length (s)	Views	Likes	Comment s	Share s	Avg. % Watche d
Difference between earthquake magnitude and intensity	10/25/2021	57	1,606	189 (12)	4 (0.25)	6 (0.37)	34
Difference between hazard and risk	11/27/2021	38	1,562	110 (7)	1 (0.07)	1 (0.07)	36
Attending a scientific meeting, Geological Society of America 2021 meeting	10/12/2021	60	1,539	87 (6)	8 (0.53)	9 (0.60)	25
Earthquakeyoga(Demonstratingtypesseismic waves)	10/13/2021	59	1,511	58 (4)	6 (0.43)	6 (0.43)	18
Different earthquake waves: P waves and S waves	10/27/2021	56	1,101	135 (12)	5 (0.44)	1 (0.09)	34
Call for 'Ask a Geoscientist' questions	10/25/2021	11	863	59 (6)	3 (0.33)	1 (0.11)	49
Demonstrating types of faults using candy bars	10/29/2021	59	840	110 (8)	6 (0.19)	5 (0.13)	35
Wave refraction explained	11/18/2021	39	815	62 (7)	1 (0.12)	0 (0.00)	37
How GPS is used to monitor Earth's systems	10/23/2021	50	775	78 (10)	4 (0.50)	1 (0.12)	27
Mandalorian "baby seismometer" meme	10/26/2021	9	522	27 (7)	1 (0.27)	0 (0.00)	76

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Table 3. The ten least viewed videos and corresponding metrics on the Terra Explore account between 10/8/2021 and 2/6/2022. ER

44 = engagement rate (Metric / Audience Reached *100). These videos correspond with #39–48 in Fig. 4.



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Figure 4. Percentage of video views by section (*For You* page, personal profile, *Following*, hashtag, unknown), with videos ranked from the most (1) to the least (48) viewed (See Tables 2 and 3 for the ten most and ten least viewed videos). The videos with the highest number of views received nearly all (~97%) of their views from the *For You* page. The seven most viewed videos each received over 90,000 views.

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251 **6.2 Video view duration and engagement rate**

252 The average percentage of time a video was viewed was 44% of its duration, and 19% of users on average watched 253 the full duration of a video. We evaluated the relationship between the average view duration of a video (%) and the number 254 of video views based on the length of the video (< 30 seconds, 30 seconds to 1 minute, 1 to 2 minutes, and > 2 minutes in 255 duration) to see if the longer that someone watches a video the more it will be promoted to other users, resulting in higher 256 views (Fig. 5). Amongst all videos, there is a weak positive correlation that is statistically significant between the average 257 video view duration and number of video views (r = 0.37, p = 0.008). Amongst the individual video length populations, only 258 videos between 30 s to 1 min long showed a statistically significant correlation between average video view duration and 259 number of video views (r = 0.57, p = 0.002). Videos < 30 s averaged the highest average view duration (63%). However, there 260 is a statistically significant negative correlation between the average video view duration and the length of a video (r = -0.41, 261 p = 0.004) (SF6), indicating that the average view duration is in part tied to the length of the video itself.

Videos had average engagement rates of 10%, 0.38%, and 0.21% for likes, comments, and shares, respectively. These engagement rates are similar to the engagement rates of other analyzed educational science content on TikTok (Habibi and Salim, 2021). We found a statistically significant strong positive correlation between the number of video views and the engagement rate of likes for videos with over 90,000 views (r = 0.90, p = 0.006). However, there is no statistically significant correlation between the number of video views and the engagement rate of likes for videos with fewer than 90,000 views (p > 0.05). We also observe no statistically significant correlation between the number of video views and the engagement rate of comments or shares (p > 0.05) (**Fig. 6**). Therefore, videos that received a large number of views (>90,000) did not necessarily have a higher engagement rate than did videos with far fewer views (~2,000).

270 We observed no statistically significant correlation between the average video view duration (%) and the engagement 271 rate of likes, comments, or shares (p > 0.05) (Fig. 7), two factors that are hypothesized to strongly impact the reach (views) a 272 video can receive. Just because a user watches more of a video, that does not indicate that they are more likely to engage with 273 the video. However, our analyses indicated that the average video view duration is in part tied to the length of the video. In 274 looking at video length, we found a weak positive correlation that is statistically significant between the length of a video and 275 the engagement rate of likes (r = 0.34, p = 0.017). There was no statistically significant correlation between video length and 276 the engagement rate of comments (p > 0.05), but there was a weak to moderate positive relationship that is statistically 277 significant between video length and the engagement rate of shares (r = 0.46, p = 0.001). Thus, longer videos tended to have 278 higher engagement rates (Fig. 8).





Figure 5. Average percentage of the video viewed based on the length of the video (< 30 seconds, 30 seconds to 1 minute, 1 to 2 minutes, and > 2 minutes) compared to the number of video views. Note that video views are shown on a logarithmic scale. There is a weak positive correlation that is statistically significant (r = 0.37, p = 0.008). See Supplementary Materials for full correlation analysis.

● Likes ■ Comments ▲ Shares



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285 Figure 6. Engagement rate of likes, comments, and shares from each video compared with video views (plotted on log scale). There 286 is a statistically significant strong positive correlation between the number of video views and the engagement rate of likes for videos 287 with over 90,000 views (r = 0.90, p = 0.006), but no statistically significant correlation between the number of video views and the 288 engagement rate of likes for videos with less than 90,000 views (p > 0.05). There is no statistically significant correlation between the number of video views and the engagement rate of comments or shares (p > 0.05). See Supplementary Materials for full correlation

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290 analysis.



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Figure 7. Engagement rates from each video compared with the average view duration (%) of the video. There is no statistically significant correlation with the average view duration and any engagement rate metric (p >0.05). See Supplementary Materials for full correlation analysis.



Figure 8. Engagement rates from each video compared with the duration of the video. Short videos under 20 seconds have a lower overall engagement rate than do longer videos. There is a weak positive correlation that is statistically significant between the length of a video and the engagement rate of likes (r = 0.34, p = 0.017), and a weak to moderate positive relationship that is statistically significant between video length and the engagement rate of shares (r = 0.46, p = 0.001). There is no statistically significant correlation between video length and the engagement rate of comments (p > 0.05). See Supplementary Materials for full correlation analysis.

301 6.3 Hashtags

Across our 48 published videos, we used a total of 81 unique hashtags. Our videos most commonly used the hashtags "geophysics," "geology," and "earthquake" (**Table 4**). Even though the hashtags "geophysics" and "geology" were used on the most videos, videos that used the hashtag "earthquake" generated the most cumulative views. Hashtags like "SanAndreas" and "California" that were only used in four videos were also associated with a large number of views.

Only one video had higher than 1% of its views come directly from searching for hashtags or clicking on a hashtag to view videos (video ranked number 11 on **Fig. 5**). That video, explaining the Hunga Tonga-Hunga Ha'apai volcanic eruption in January 2022, received 3% of its views from direct hashtag searches. This post included the hashtags "HungaTonga" and "Tonga," from which the views were likely derived.

Between October 2021 and February 2022, the cumulative views of all videos using the "geology" hashtag across TikTok increased by 167.5 million views, with Terra Explore videos contributing 9% of those views, and the "geophysics" hashtag increased by 1.2 million views, with Terra Explore videos contributing 89% of those views.

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Hashtag	# of Videos	Cumulative Views		
	Used in			
Geophysics	38	1,073,171		
Geology	36	1,511,813		
Earthquake	31	1,974,026		
Seismology	22	949,459		
Science	8	148,978		
Lidar	6	110,251		
GPS	5	12,190		
LearnOnTikTok	5	32,854		
SanAndreas	4	418,542		
Earthquakes	4	11,651		
FYP	4	15,079		
California	4	1,013,653		
Geoscience	3	4,221		

Geodesy	3	5,861
SciComm	3	187,259

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Table 4. Top 15 most commonly used hashtags on the Terra Explore videos indicating the number of videos they were used on, and 316 the cumulative views associated with hashtag use. (FYP = "For You Page.")

6.4 GMV videos 317

318 Nine of the 48 videos produced featured ground motion visualizations (GMVs) of recent notable earthquakes. All 319 nine of the GMV videos highlighted earthquakes that were magnitude 6 or larger. GMV videos were uploaded the day of or 320 the day after an earthquake occurred and were posted approximately twice a month during this four month duration. Views for 321 these videos ranged between 2,106 and 372,300 views. Eight videos were under 60 seconds in length, and one was 100 seconds 322 long. The videos with the most views had a duration between 30-60 seconds, but there is no statistically significant correlation 323 between video length and the number of views (p > 0.05) (Fig. 9a). We found that there is a strong positive statistically 324 significant correlation between the average video view duration and the number of video views (r = 0.847, p = 0.004) (Fig. 325 **9b**). There was no statistically significant correlation between the number of video views and the engagement rate of likes. 326 comments, or shares (p > 0.05) (Fig. 9c). Videos were posted at different times during the day, with the videos that received 327 the most views being posted in the morning Mountain Standard Time (MST) (UTC-7). However, there is no statistically 328 significant correlation between time posted and number of views (p > 0.05) (Fig. 9d). Regardless of the global location where 329 the earthquake occurred, 84% of each videos' views on average came from users located within the United States. Therefore, 330 these GMV videos were largely not being shown to users in countries where the earthquake occurred, but rather shown to users 331 in North America (where the visualization is focused).



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Figure 9. Video views of GMV videos on a log scale compared with (a) the duration of the video, (b) the average duration a video was watched, (c) the engagement rates of the video, and (d) the time of day the video was posted (MST) (UTC-7). There is a strong positive statistically significant correlation between the average video view duration and the number of video views (r = 0.847, p = 0.004), but there is no statistically significant correlation (p > 0.05) between the other parameters. See Supplementary Materials for full correlation analyses.

338 7 Discussion

339 7.1 Video views and viewership

The vast number of video views received from the *For You* page rather than the *Following* feed demonstrates that content on TikTok is primarily consumed from the *For You* page, and that the success of a video largely hinges on whether it will continue to be shown to more users on this algorithmic feed. Our findings are in accordance with TikTok's internal data that users spend the majority of time (nearly 70%) on the *For You* page on the app (Stokel-Walker, 2020). With users spending less time on the *Following* feed, this feed provides a lower overall source of video views. Even when a person is following an account, those videos can still be shown on the *For You* page. The view, although coming from a follower, would still be marked as a view from the *For You* page. Our findings support other work showing that video views on TikTok are less dependent on the number of followers/subscribers as compared to other platforms like YouTube (Guinaudeau et al., 2021).

While the number of followers can support the credibility of an account, a large number of followers is not required to reach

a large viewership on TikTok, and having a high number of followers on TikTok does not guarantee equally high video views.

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350 Short videos (~20 seconds or less) on TikTok may have a higher potential to accumulate views as they can easily be 351 played in a "loop" like a GIF, but our data suggests that users are more likely to engage and interact with longer (>60 s) 352 educational science videos (Fig. 8). Even though some of these longer videos did not perform particularly well in terms of 353 view counts (Fig. 6), they still tended to have relatively high engagement rates. Videos < 20 s had an average engagement rate 354 of 6.5% for likes, whereas videos between 40 s and 2 minutes had an average engagement rate of 10% for likes. While it is 355 suspected that higher engagement rates on TikTok videos lead to higher views (Klug et al., 2021), we did not observe any clear 356 relationship between the number of video views and the engagement rate (Fig. 6). We found that only for our most highly 357 viewed videos (videos with >90,000 views) there was a strong positive correlation between the number of views and the 358 engagement rate of likes. High engagement rates on videos with lower view counts may come from people who are following 359 the account and have an expressed interest in the subject.

360 The lack of any discernible relationship between the average view duration of a video and the engagement rate (Fig. 361 7) demonstrates that these two factors are not coupled and suggests that a video likely needs both a high engagement rate and 362 a high view duration to be promoted within algorithmic feeds. Our top ten most viewed videos had an average view duration 363 of 58% and an average engagement rate of 11% for likes (Table 2), greater than the average view duration of 44% and 10% 364 likes across all of our videos. Unlike platforms like YouTube where users select which video to view, users on TikTok choose 365 whether to continue viewing a video they were automatically shown. While some highly interested users may watch the 366 majority of the video and engage with it, if too many users quickly scroll away, it will negatively impact the average view 367 duration of the video and its reach. If the intent of the science content is to maximize the engagement level from the viewer, 368 then producing longer (> 60 s) lecture-style videos is preferable. However, the reach of the video may be sacrificed with longer 369 videos if too many users scroll away from the video too quickly. Thus, the communication objectives should dictate what video 370 type and duration is used.

Unlike platforms such as Twitter where users may search for a specific hashtag to view content related to a topic (Chang and Iyer, 2012), viewer behavior in regard to educational science content on TikTok largely does not entail searching for specific hashtags to view content, unless related to a specific newsworthy event. On average, only 0.02% of our video views came directly from hashtag searches. Thus, hashtags appear most useful in categorizing content, which may aid in its algorithmic discovery on the *For You* page—although the factors used in TikTok's algorithm have not been publicly disclosed. The use of a hashtag itself will not necessarily determine the popularity of a video, but rather the hashtag is reflective of the content and subject matter of the video.

We also found that there was little relationship between the time a video was posted and how well it performed (**Fig. 2, 9d**). Post time optimization is the concept of posting social media content at a time when most users/followers are active and online and likely to see the content, thus increasing its potential reach. As the majority of our account's followers are 381 located within the United States, we focused our posting during daytime hours within the U.S. before followers would logoff 382 online for the night. However, it would be interesting, especially if wanting to attract an international audience, to see how 383 videos perform if they are posted during nighttime hours in the U.S. We anticipate that videos should be posted at a time local 384 to when the desired or majority audience is primarily online.

385 **7.2 Generating high video reach and engagement**

While intrinsic features such as the length of the video may impact engagement metrics, the content of the video itself is an equally important consideration when attempting to reach a wide audience and generate high engagement. Based on our most viewed videos (**Table 2**), we found that videos with the highest reach focused on recent newsworthy events (e.g., an earthquake) or discussed specific location-based geology. These findings support pedagogical research that suggests that recent, real-world incident examples should be included when teaching geoscience or environmental science topics to increase student engagement and interest (Singh et al., 2022).

Given our organizational missions, a high percentage of our video content focused on earthquakes and seismology, with all notable recent earthquakes being covered in GMV videos. These videos generated high interest by providing real-time information about earthquakes in the news, shown in a data visualization format that was likely novel to the public. User comments on GMV videos typically expressed how it was a unique, interesting visualization that they had not seen before. Additionally, by showing the motion recorded on seismometers across North America where the vast majority of our followers are located, users in those areas were able to view how the ground moved near them, adding a level of personal, location-based interest. User comments also often expressed interest in the distribution of seismic instruments in North America.

399 We also found high reach and engagement with videos covering other relevant, newsworthy geology topics. For 400 example, we produced videos covering the January 2022 Hunga Tonga-Hunga Ha'apai volcanic eruption and the anniversary 401 of the January 1700 Cascadia earthquake and tsunami. These videos were our eleventh and eighth most viewed videos, 402 respectively, and were a "lecture-style" that primarily used image overlays. Comments left on these videos typically expressed 403 that the users enjoyed the overview of information and how it was conveyed. The Hunga Tonga video was also shown to a 404 wider international audience, with only 66% of views coming from users located in the United States. Thus, if the focus of the 405 video is on a specific international location/event, the video may be served to a broader audience. Research from educational 406 geoscience videos on YouTube also suggests that short, timely videos about natural hazards are useful for engaging the public, 407 especially those who live near where the hazards occur (Wang et al., 2022).

Videos describing geologic processes or features were most successful when they were tied to a specific, recognizable location. These videos were done in a "lecture style," typically using "green screen" backgrounds and image overlays. Based on user comments, videos that were about a geologic feature in a specific location that were tagged with location indicators (e.g., #Hayward #California; #Hollister #California) were shown to many people who live in those cities. Although these users may not have previously interacted with or shown interest in geoscience content, we hypothesize that location-based information was used to deliver these videos to their *For You* page. Based on these video comments, the high engagement was 414 generated in part by users from those geographic locations. Many commented that they were from the locations being covered;

415 some recognized features in the town they were familiar with, and others learned something new and interesting about the 416 geology of where they live.

417 In spite of these data, there is still complexity in understanding why certain videos perform better than others. For 418 example, we produced two demonstration videos using food as analogs for geologic concepts. A video using spaghetti strands 419 to demonstrate earthquake magnitude received 305,500 views and was our third most viewed video (Table 2), while a video 420 using Halloween candy bars to demonstrate types of faults received only 840 views and was our fourth least viewed video 421 (Table 3). Both of these videos presented concepts that were made easy for the viewer to understand by using common food 422 items, and they were both posted on the same day of the week (Friday) and before noon MST (6 pm UTC). It is possible that 423 for demonstration videos like these—which are more analogous to chemistry or physics content showing experiments—that a 424 shorter video duration is better for achieving high reach and engagement. The earthquake spaghetti video was 34 seconds long, 425 while the candy bar faults video was 59 seconds long. A viewer may be more likely to watch a longer lecture-style video but 426 may prefer shorter, dynamic demonstration videos.

427 **7.3 Gender of viewers and target audiences**

428 Although we used the hashtags #WomenInSTEM and #WomenInScience on a number of videos, the majority of the 429 Terra Explore account's followers remained male (~64% male). Given the fact that 61% of users on TikTok are female 430 (Statista, 2021), the gender breakdown of our followers is not representative of the demographics of TikTok users. The large 431 percentage (25%) of TikTok users that are under the age of 19 (Statista, 2022a) represents a critical demographic for 432 maintaining interest in STEM. Research has shown that STEM interest begins to decline in middle school (ages 11–13), 433 especially for girls (Archer et al., 2010; Riegle-Crumb et al. 2017; Sadler et al., 2012). Additionally, many students have little 434 exposure to the geosciences during their primary and secondary education (grades K-12 in the US) (Dodick and Orion, 2003; 435 Lewis and Baker, 2010; Ridky, 2002), which means that young girls are often left without geoscience role models. Through 436 TikTok, we can engage with this critical demographic and hope to inspire young women to continue an interest in pursuing 437 STEM and see themselves as future STEM professionals.

438 However, the presentation of material by female scientists and the use of hashtags like #WomenInSTEM or 439 #WomenInScience on TikTok may not be enough to gain female followers and viewership; the content itself may also have to 440 focus on gender to be shown on women's For You pages. Experience from the lead author's personal TikTok account suggests 441 that women may be more likely to receive videos about gender discrimination and gender disparity on their For You page than 442 educational science content, even if they are interested in science. The lead author made a video on their personal TikTok 443 account discussing how their follower base had become overwhelmingly male (75% male followers) and used the 444 #WomenInSTEM hashtag. The video gained wide female viewership, leading to a large increase in followers and flipping the 445 percentage of followers to 86.1% female. The second author also had a similar experience on their personal TikTok after making a series of posts about the IF/THEN organization and International Women's Day, with male following decreasing
 from 65% to 17%.

As TikTok did not provide information about the age of followers or viewers for videos posted prior to August 2022, we are unable to evaluate the full demographics of who our videos reach. Future work may benefit from creating and analyzing new videos where the gender percentage and age of viewers is reported, or from using the paid 'promote' feature that allows accounts to target specific demographics.

452 **7.4 Ethics of TikTok data usage**

When conducting research on social media platforms, it is necessary to address the ethical issues related to privacy, anonymity, and consent of human subjects (Vitak et al., 2016). Kanthawala et al. (2022) discusses the specific ethical considerations related to research on TikTok given its heavier dependence on algorithmic curation and its younger user base. More so than other social media platforms, TikTok has faced scrutiny over the data that it collects from its users and user security. TikTok has previously paid \$92 million to settle dozens of lawsuits that allege that users' personal data was tracked and sold to advertisers in violation of state and federal law (Allyn, 2021). There additionally has been scrutiny over the biometric data including "faceprints" and "voiceprints" that TikTok can now collect from users (McCluskey, 2021).

According to TikTok's privacy policy, TikTok collects information that the user provides when creating an account, such as their name, age, and email, as well as information from other sources, such as linked social media accounts and thirdparty services, and device information, including the user's approximate location (TikTok, 2021b). By creating a user account and agreeing to the terms and conditions, TikTok users provide their consent to have their information collected. However, many users are unlikely to read the privacy policy when creating an account and will not be aware of what they are consenting to.

Although TikTok provides analytical information about the gender breakdown of an account's followers, users do not provide information on their gender when registering for an account. We hypothesize that TikTok either acquires gender information through connected social media accounts or assumes the gender of an account based on a user's activity on the app. We are therefore unable to determine how accurate the information provided on the gender of followers is and whether users are aware that this information is assumed or collected on their behalf. However, we have no reason to believe that this information would be inaccurate due to TikTok's heavy data mining and the fact that this same demographic information is also provided to million-dollar corporations for targeted advertising campaigns.

The information and data we analyze in this study are restricted to video view duration and engagement metrics and are not related to in-depth personal user information that TikTok may collect. We do not evaluate or analyze the individual followers of the Terra Explore account or include specific comments from any users, providing full anonymity. The data on video views, likes, comments, and shares are fully publicly available to all users, and only total cumulative play time, average duration the video was watched, percentage of viewers who watched the full video, and the percentage of video views by section and region is private to the account user. Therefore, the data used are largely public and there is minimal risk to the individual users from this research. While TikTok as a platform may have larger ethical concerns that are beyond the scope of
 this study, we argue that the data used in this research are ethical.

481 **7.5 Potential for science communication on TikTok**

482 Data collected over this four-month timespan demonstrates that TikTok provides significant potential for reach and 483 growth of science communication. As a brand-new account, the second video we posted gained over 165,000 views within the 484 first few days and now has over 370,000 views. The algorithm-driven (rather than follower-driven) nature of TikTok creates 485 a low barrier of entry for new creators. An account does not have to focus on creating a large following in order to achieve a 486 wide reach. As well, there are no materials required to produce content other than a mobile smartphone with a camera. 487 However, given that views from the *Following* feed constitute a low overall percentage of views, there may be pressure to 488 constantly produce "viral" videos that are shown widely on the For You page. Having a large number of followers does not 489 guarantee that a video will be seen by a large number of people.

490 Despite potential shortcomings, TikTok presents an opportunity to deliver educational science videos to wide 491 audiences with relatively little effort. All six Terra Explore videos related to lidar were cross-posted on OpenTopography's 492 YouTube channel as "Shorts," which is YouTube's TikTok-like short-form video category. The OpenTopography YouTube 493 channel had 1,900 subscribers at this time. These videos received an average of only 35 views on YouTube, while the same 494 videos received between 2,422 and 133,500 views on TikTok. Starting in February 2022, we began cross-posting GMV videos 495 for recent earthquakes on IRIS's Instagram account as "Reels," Instagram's TikTok-like video category. The IRIS Instagram 496 account has approximately 2,300 followers as of Fall 2022. The exact same videos received on average five times more views 497 on TikTok than they did on Instagram. The vast discrepancy in views of the exact same videos posted on different platforms 498 highlights the benefits of TikTok's recommendation algorithm in reaching a wide audience.

499 A potential challenge is that TikTok videos require an engaging, charismatic video presenter: two people could create 500 the same video, but one video might perform significantly better if one host has a more natural, charismatic presentation style. 501 We have not evaluated how this factor impacts video performance. In addition to the content of the video itself, practice in the 502 presentation style of videos (which is beyond the scope of this study) is also an important component for science 503 communicators to consider. As well, we acknowledge that TikTok's recommendation algorithm may change over time, 504 although we don't anticipate such significant changes would occur in a short amount of time that would invalidate our results. 505 Future studies will benefit from continued analysis of video content, as well as a more qualitative evaluation of the impact and 506 effectiveness of the science communication.

- 507 We thus recommend the following for the best chances of high reach and engagement with science communication 508 on TikTok:
- Produce lecture-style videos using green screen and image overlay effects that are approximately 60 seconds or
 longer in duration.
- Produce demonstration or experiment-style videos that are ≤ 30 seconds in duration.

- Choose video topics that can be related to recent newsworthy events or are tied to a specific place or location.
- Include gender-related topics to reach a wider female audience.
- Select hashtags that are relevant to the video topic, especially ones including locations to provide additional
 algorithmic video context.
- Pay attention to videos that receive the majority of their views from the *For You* page and work to replicate
 those qualities.

518 8 Future plans

As we continue to run the Terra Explore account, we plan to expand the scope of the geoscience topics that we cover and to continue analyses of how to best maximize reach and engagement from these videos. While the geoscience content of our videos has been largely focused on earthquakes thus far, we plan to include discussion of other natural hazards like volcanic eruptions, floods, landslides, etc. This expansion segues into an opportunity to produce content related to climate and climate change. Encouraging science curiosity helps to neutralize polarization on topics like climate change (Kahan et al., 2017), and TikTok provides an ideal platform to promote such curiosity.

While all of our videos analyzed thus far were created in home offices, we believe producing content from the field could generate high video views and user engagement. Instead of merely showing photos, field-based videos could present and highlight seismic or GPS instruments and their installation and maintenance, geologic features you can see in the field, or how drones are used in geoscience, among many other possibilities. Five field-based videos that we created between April to September 2022 after our analytical study period received between 3,620 and 779,100 views on TikTok. Given the more costly and time-intensive nature of producing videos on location, a full analysis of their metrics would be necessary to see if they have higher reach and engagement than similar videos produced in home offices.

To better reach target audiences like young women and girls and to improve the overall diversity of scientists shown in popular media, we would like to produce a "Meet the Scientist" video series to highlight female and nonbinary geoscientists, sharing both their research and experiences. These types of videos would complement and expand on the IF/THEN "Women in Geoscience" video series available on the IRIS YouTube channel that features women in the geosciences sharing their work and interests. The geosciences remain one of the least racially and ethnically diverse out of all the STEM fields (Bernard and Cooperdock, 2018), and "Meet the Scientist" interviews featuring underrepresented scientists on TikTok will help to increase the visibility of minoritized scientists and show the broad diversity of scientists and careers that exist in geoscience.

539 9 Conclusions

540 TikTok offers significant potential for reach and growth of science communication content. TikTok functions 541 primarily on a model of algorithmic recommendations rather than a follower-based model, which provides a low barrier to 542 entry for new creators. Although the exact nature of the TikTok algorithm is unknown and therefore somewhat challenging in 543 reaching target audiences, new age and gender analytics that were released in August 2022 may provide additional insight into 544 the demographics that are engaging with content. In the assessment of our geoscience content, lecture-style videos that were 545 approximately a minute long yielded the highest reach and engagement. Video topics that discussed recent newsworthy events 546 (i.e., earthquakes) or discussed specific location-based geology resulted in the highest reach and engagement. Shorter-form 547 content (< 30 seconds) did not perform as well unless it was a demonstration-style video, which would be more analogous to 548 the physics and chemistry experiments that are commonly seen on TikTok. Unlike other platforms, user behavior on TikTok 549 does not entail searching for or browsing specific hashtags to view educational science videos. Rather, videos are 550 predominantly viewed via the For You page, and hashtags provide a way to categorize and describe content—information 551 which may or may not be used by TikTok's AI to show the video to audiences. Although this study focuses on the geosciences, 552 we anticipate that our findings will be broadly applicable to other scientific disciplines and will allow science communicators 553 success in reaching broad audiences.

554 Data availability

555 The video data analyzed in this study is accessible at <u>https://doi.org/10.6084/m9.figshare.20069333</u> (Zawacki, 2022).

556 Author contributions

557 The Terra Explore videos analyzed here were created by EZ and WB, in addition to SJ. DC provided project administration 558 and coordination. EZ collected and analyzed the data and wrote the primary draft. WB, SJ, and DC contributed to the writing, 559 review, and editing.

560 **Competing interests**

561 The authors declare that they have no conflict of interest.

562 Acknowledgements

- 563 We thank two anonymous reviewers for their helpful comments on an earlier version of this manuscript. We thank Zhiang
- 564 Chen for their assistance with the correlation analyses. We thank Christopher Crosby for project guidance.

565 Financial statement

566 This work was supported by NSF awards #1724794, #1948997, #1948994, and #1948857.

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