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Sharing the Importance of Ocean Salinity Beyond the Scientific Community

By Annette deCharon, Carla Companion, Ryan Cope, and Lisa Taylor

ABSTRACT. The Aquarius satellite mission and Salinity Processes in the Upper-ocean Regional Study (SPURS) are providing the scientific community with new insights into the role seawater salinity plays in the Earth system. Aquarius and SPURS scientists and engineers, working with the University of Maine-based Salinity Public Engagement and Communications team, developed webinars that focused on how these programs' findings increase knowledge about topics such as the water cycle, ocean circulation, and climate. Direct involvement of research scientists and engineers was key to the success of these efforts. These experts learned how to use interactive concept maps to "deconstruct" scientific content into simpler graphical formats for their presentations. A benefit to webinar participants, presenters, and facilitators was that they honed their critical thinking skills. In addition, the webinars allow people traditionally not represented in science, technology, engineering and math to gain better access to high-quality NASA materials. Post-event audience evaluation data provide valuable feedback on the impacts of sharing the results of ocean salinity research beyond the scientific community.

BACKGROUND

Several ocean-related commissions and committees created by the US Congress emphasized the need for increased national ocean science literacy to allow citizens to understand critical issues associated with the "grand challenges" of our time spanning ecology, trade, energy exploration, climate change, biodiversity, the ocean, and human health (e.g., US Commission on Ocean Policy, 2004, US Department of Education, 2007). The Joint Ocean Commission Initiative (2009) highlighted the need for increased attention to the ocean's role in the global water cycle. Citing potential impacts of ocean-atmosphere events such as El Niño and La Niña on the US economy, they acknowledged a need for increased capacity to anticipate longer-term trends in precipitation, including both drought and flooding.

To measure the public's perceptions and use of the ocean, The Ocean Project (2009) conducted an online survey from late July through early November 2008, collecting qualitative and quantitative data from 22,000 Americans. A summary of their findings states that, of the sampled respondents, 35% could not identify a single ocean-related issue affecting the United States. They also concluded that the content knowledge possessed by the American public is superficial. For example, the public "does not associate or otherwise connect the ocean with climate change and/or global warming." And while the respondents were generally concerned about climate change, less than half of the sample population indicated a belief that "climate change is negatively impacting the health of the ocean" (The Ocean Project, 2009).

The Ocean Project (2009) also reported that the primary and dominant means by which the American public accesses information about ocean-related content is the Internet. According to their report, "as a conduit for information, the Internet operates to the near exclusion of every other medium." Given this response, and the international scope of the Aquarius satellite mission and the Salinity Processes in the Upper-ocean Regional Study (SPURS), the University of Maine-based Salinity Public Engagement and Communications (SPEC) team piloted salinity-themed webinars as a potentially efficient way to share the science and engineering content of these programs with a broad audience.

A key component in the development of these webinars was using concept maps to both design and deliver content. Concept maps are powerful tools for visualizing, organizing, and linking ideas and processes (Fonseca et al., 2004; Preszler, 2004; Yarden et al., 2004). By displaying the relationships among concepts using connecting lines and descriptive phrases, complex science can be broken down into its constituent underpinnings, providing a type of "road map" for researchers to clearly organize and explain the logic of their work (deCharon et al., 2013; see Figure 1 for an example of a concept map). Concept mapping, a technique that was new to all scientists and engineers who participated in these salinity-related webinars (Table 1), is an empirically validated learning practice that effectively transmits information and builds critical thinking skills (Ausubel, 2000; PCAST, 2012). Critical thinking is the mental process of conceptualizing, applying, analyzing, synthesizing, and evaluating information to reach an answer or conclusion.

Having trained over 275 faculty- and graduate-level scientists to develop concept maps on projects related to ocean sciences, the SPEC team explored how to translate technical information about ocean salinity to a broad audience using this technique (Ennis, 1985; McPeck, 1990; Bailin et al., 1999). For example, Aquarius and SPURS scientists and engineers successfully used concept maps to deliver information about how their research is related to other domains, including societal issues such as climate change. In addition, the use of concept maps to communicate about NASA science and engineering allows the public to follow experts' paths of critical thinking, including "the mental processes, strategies, and representations [these experts] use to solve problems, [and] make decisions" (Sternberg, 1986).

DESIGN OF THE WEBINAR DELIVERY MODELS

To support the use and development of concept maps as collaboration, communication, and critical thinking tools, SPEC created and tested custom online concept mapping software, the Concept-Linked Integrated Media Builder (CLIMB; http://cosee.umaine.edu/climb). Initially published in 2007, CLIMB is linked to a database with over 6,000 scientist-vetted assets such as images, videos, teaching resources, and news items. Anyone who has registered a cost-free account on CLIMB can use these resources in their own concept maps. The Aquarius and SPURS scientists and engineers involved in webinar development added significantly to the CLIMB database, making it even more valuable.

The interactive, online concept maps used in the 11 salinity-themed webinars allow information to be viewed in three ways:

1. **Maps** to convey a story line with high-level topics (i.e., "concepts") with linking phrases, usually designed to answer a specific "Focus Question" (Table 1)
2. **Color-coded concepts** that show thematic groupings, which can be hidden/revealed based on their color using CLIMB software
3. **Images, videos, and other resources** that provide detailed information and are accessed from the CLIMB database by clicking on concepts

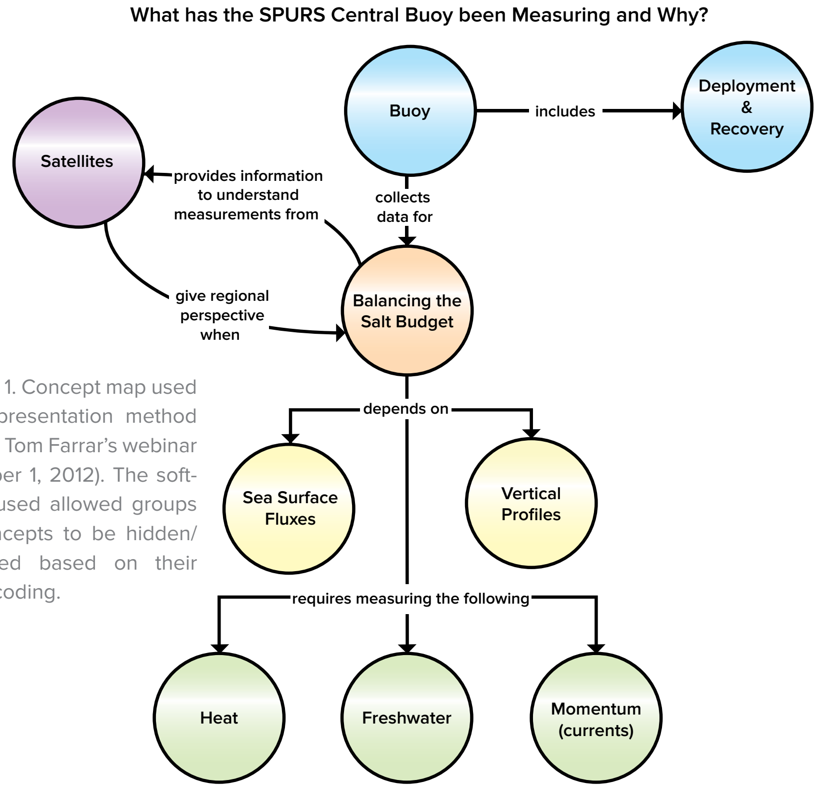


Figure 1. Concept map used as a presentation method during Tom Farrar's webinar (October 1, 2012). The software used allowed groups of concepts to be hidden/revealed based on their color coding.

TABLE 1. Webinar presenters, focus questions or topics.

SPURS Webinar Series cosee.umaine.edu/coseeos/spurs/webinars.htm	
Feb–Mar 2013	Eric Lindstrom, NASA Headquarters • *What is a sensor web and how does it help SPURS?*
	Ray Schmitt, Woods Hole Oceanographic Institution (WHOI) • *What affects ocean salinity & why should we care?*
	Fred Bingham, University of North Carolina Wilmington • *What have we learned about the SPURS sites & what's next?*
Sep–Oct 2013	Julius Busecke, Columbia University graduate student • *How does the atmosphere affect land? How does the atmosphere affect the ocean?*
	Stephen Riser, University of Washington • *How does Argo help us better understand the global ocean?* • *How do advanced Argo floats help us better understand SPURS?*
	Tom Farrar, WHOI • *What has the SPURS central buoy been measuring and why?*

Aquarius Webinar Series aquarius.umaine.edu/cgi/sci_webinars.htm	
May 2011	Gary Lagerloef (Earth & Space Research); Yi Chao (Remote Sensing Solutions Inc.) • *What are the effects of sea surface salinity on ocean circulation?* • *How does understanding salinity help us understand climate change?*
Jan 2012	Gary Lagerloef; Yi Chao; David Le Vine (NASA Goddard Space Flight Center, GSFC) • *How was the technology for Aquarius developed and how does it work? How do we cover the globe with Aquarius data?*
May 2012	Susan Lozier (Duke University) • *Using Aquarius data: How is inquiry-driven education brought to the undergraduate classroom?*
Oct 2012	Amri Hernandez-Pellerano; Fernando Pellerano; Shannon Rodriguez (NASA GSFC) •*¿Que es salinidad? (What is salinity?)* •*¿Como se mide la salinidad desde el espacio? (How do we measure salinity from space?)*
Nov 2013	Sandra Torrusio (Comisión Nacional de Actividades Espaciales, CONAE); Monica Rabolli (CONAE); Jorge Vazquez (NASA JPL) • *Trazando mapas de nuestro mundo con Aquarius/SAC-D (Mapping our world with Aquarius/SAC-D)* • *Colaboración internacional (International collaboration)* • *Historias cartográficas alrededor del mundo (Mapping stories around the world)*

Box 1. The Earth Observatory

The Earth Observatory hosts several blogs from NASA field campaigns, including SPURS (http://earthobservatory.nasa.gov/blogs/fromthefield/category/spurs). Over two months, Eric Lindstrom (NASA Physical Oceanography Program Scientist) authored 32 blog posts and handled all user-contributed comments and questions. The second SPURS webinar series occurred midway through the field campaign, and the blog provided many useful resources for concept maps and webinar archive pages. Posts covered a wide range of topics, including salinity science, shipboard life and operations, instrument deployments, data management strategies, and a call from the Commander of the International Space Station, Sunita "Suni" Williams. Throughout the blog, special emphasis was placed on the people behind SPURS, including scientists representing various career stages.

Leading up to the webinar events, SPEC worked closely with the presenters to evaluate, develop, and/or refine each of these information types. The process began with an online videoconference to brainstorm ideas on a "Focus Question" and a list of concepts that would be appropriate for and relevant to a general public audience. In the case of a webinar series, sharing "Focus Questions" among presenters helped to ensure that various webinar topics fit together as a cohesive story. Concept maps and attached database resources were refined with presenters over subsequent weeks, usually via email. Earlier research indicates that the iterative process of concept map development benefits scientists by "identifying what they do and do not explain well" to nonscientists (deCharon et al., 2009).

The webinar content development process helped scientists and engineers break down their research into core components and use creative thinking to make new connections for nonscientists (Ennis, 1985; Bailin, 2002; Paul and Elder, 2006). For example, Figure 1 shows the concept map used during the October 2013 webinar featuring Tom Farrar (Woods Hole Oceanographic Institution [WHOI]) whose SPURS-related research focuses on surface and subsurface salt fluxes. Based on feedback from previous Aquarius webinars and consistent with the NASA blog about the SPURS field campaign (see Box 1), SPEC encouraged presenters to address the technology behind the measurements, including challenges in acquiring data. Farrar addressed this topic under the concept of "Deployment & Recovery." Overall, his concept map depicts how balancing the salt budget within the SPURS region requires data from both buoys and satellites. Similarly, "Sea Surface Fluxes" and "Vertical Profiles" were included to emphasize the need for data collection at and below sea level.

Critical thinking was applied both during concept-mapping exercises and when analyzing potential supporting scientific representations such as images and data graphs. For salinity-themed webinars, much of the preparation focused on collaboratively reworking the graphical material that the presenters customarily show to their peers, deconstructing it to be appropriate for nonscientists, and ensuring that it followed the storyline outlined by their concept maps.

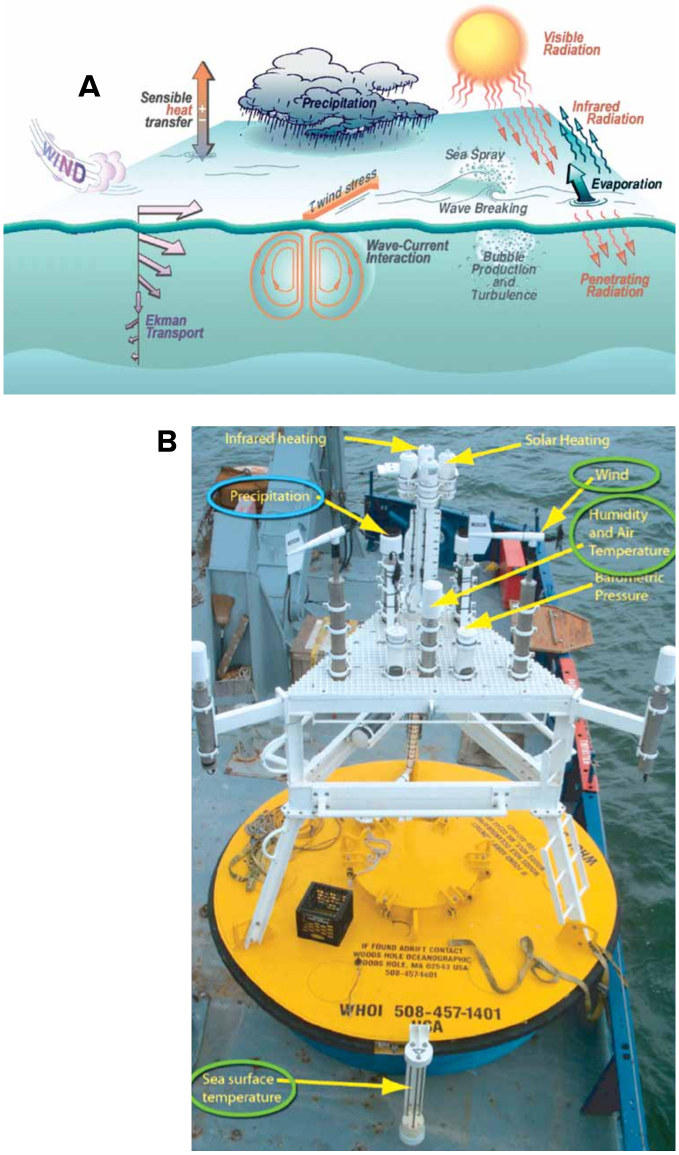
For example, much of the image deconstruction effort for Farrar's webinar focused on the three green concepts at the bottom of his concept map: Heat, Freshwater, and Momentum (Figure 1). Figure 2 shows the common set of images that was used for these concepts, including: (1) an illustration of air-sea flux processes, (2) a photo of above-water instruments on the central SPURS-1 mooring, and (3) a schematic diagram of the buoy's in-water instruments. To clarify the differences between the concepts, relevant portions of each image were correspondingly enhanced. The set of images in Figure 2 has been tailored for the "Freshwater" concept. The complexity of the air-sea flux illustration was simplified to emphasize only precipitation and evaporation (Figure 2A), while the other processes are less visible. Color-coded circles were added to Figure 2B to distinguish which above-water buoy instruments were used to measure precipitation and evaporation. The schematic diagram (Figure 2C) was masked to reveal only the in-water instruments that were used to estimate freshwater fluxes (i.e., temperature and conductivity sensors).

After the concept maps and attached resources were finalized, practice sessions were held, usually about three days before the public events. The live webinars began with featured presenters describing their content for about 40 minutes while clicking through their concept maps and associated images, videos, and other resources obtained from the CLIMB database. At the conclusion of each webinar, presenters spent about 20 minutes interactively fielding audience-submitted questions, demonstrating critical thinking by clarifying issues, defining terms, identifying assumptions, interpreting, explaining, and reasoning verbally (Ennis, 1985; Facione, 1990; Paul, 1992; Halpern, 1998).

The ratio of time spent on content delivery to time spent on fielding questions was based on participants' feedback from dozens of prior webinars conducted by the SPEC team (i.e., responses to specific post-event questions about length of time spent on various sections). Any unanswered questions, for example, those that were not relevant to a general audience, were addressed later either by the SPEC team or forwarded to the presenter.

Soon after the webinar events, the SPEC team summarized survey data from participants in written reports and delivered the results to the featured scientists and engineers. The objective of these reports was to inform the presenters on the reach and audience demographics of their webinar event, usefulness of their content, and aspects of their presentation that were particularly effective and those that could be improved. For the facilitation team, these reports also provided formative evaluation data to improve the design and implementation of future salinity-related webinars.

Advertised through various email listservs, English- and Spanish-language webinar events (Table 1) directly engaged 511 people in 38 US states/territories and 13 non-US countries, eight of which are located in Central or South America (Figure 3A). Argentina had the highest percentage (41%) of non-US participation, likely because NASA's salinity sensor, Aquarius, is onboard the Satélite de Aplicaciones Cientificas-D (SAC-D), which was built and is operated by Argentina's Comisión Nacional de Actividades Espaciales (CONAE). Registration information from 337 unique webinar participants (Figure 3B) shows that 43% described their role as educators (i.e., 31% formal and 12% informal), 14% were faculty or postdocs, 23% were undergraduates or graduate students, 4% were pre-college students (i.e., 3% high school and 1% middle school), 6% selected "other," and 10% did not provide information on their roles.



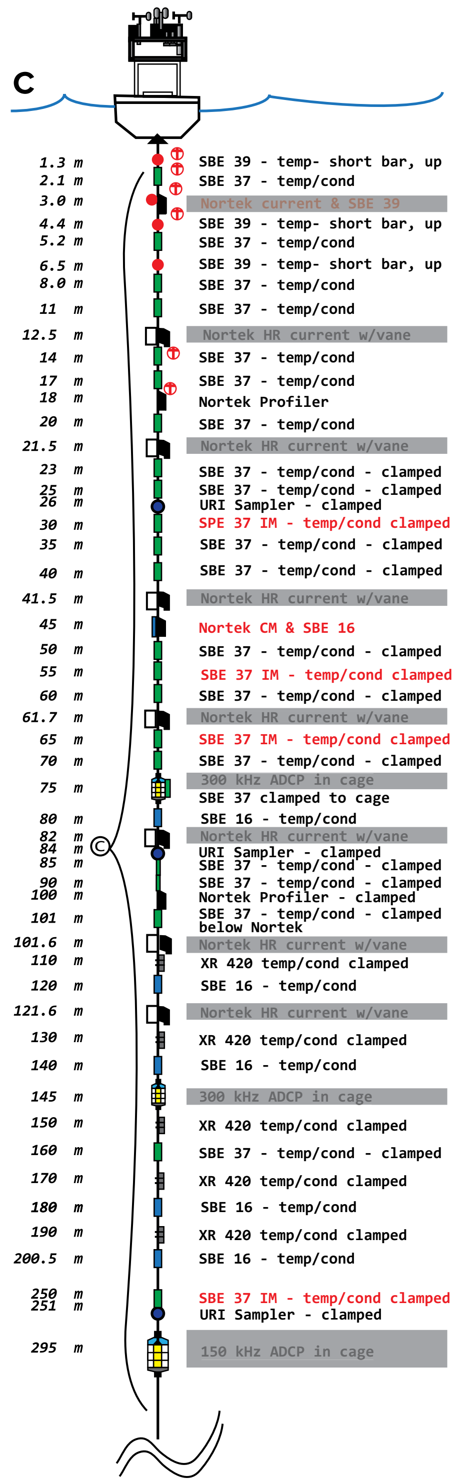


Figure 2. Enhanced images for the "Freshwater" concept. (A) Precipitation and evaporation are the most visible processes on the air-sea flux illustration. (B) The buoy instrument circled in blue contributes to an understanding of freshwater inputs (i.e., precipitation). Instruments circled in green are used to estimate evaporation. (C) Only instruments that help measure freshwater flux are revealed in this schematic diagram of in-water sensors. *All original figures are courtesy of Woods Hole Oceanographic Institution*

Box 2. Highlighting Ocean Sciences & Engineering Practices Website

The website Highlighting Ocean Sciences & Engineering Practices (http://aquarius.umaine.edu/cgi/ed_stem.htm) provides educators and the interested public with insights into modern-day ocean exploration. Emphasizing the synergies between science and engineering, video clips from salinity-themed webinars highlight the research of professional ocean scientists and engineers in various disciplines. Additional relevant content, including concept maps, images, data visualizations, graphs, and animations, accompany these clips. Materials can be accessed based on practice (e.g., asking questions, using models, carrying out investigations, designing solutions), topic (e.g., "Solving Old Problems with New Technology," "Small Scale Observations and Large Scale Ideas"), or webinar presenter (Table 1). Highlighting Ocean Sciences & Engineering Practices has been recommended by the NASA Science Mission Directorate's online Earth & Space Science Education Product Review. An independent peer-review panel, which included both scientists and educators, determined it is a relevant and appropriate resource for classroom teachers who want to provide role models of effective practice for their students. As a result, this product is included in the NASA Wavelength Digital Library (http://nasawavelength.org), which features high-quality materials developed by a national community of education and outreach professionals.

Following each webinar event, video of the presentations, embedded interactive concept maps, and transcripts of "question and answer" sessions were archived online, along with selected educational resources (see http://earthobservatory.nasa.gov/blogs/fromthefield/category/spurs). The webinars' videos and archived pages have been viewed over 24,800 times by people in almost 80 countries, efficiently providing long-term access to scientist- and engineer-vetted NASA materials on ocean salinity. Moreover, much of the archived webinar content has been repurposed into a new online resource, "Highlighting Ocean Sciences & Engineering Practices," which is designed for K–12 educators and aligned with the "Next Generation Science Standards" (http://www.nextgenscience.org; Box 2).

FINDINGS

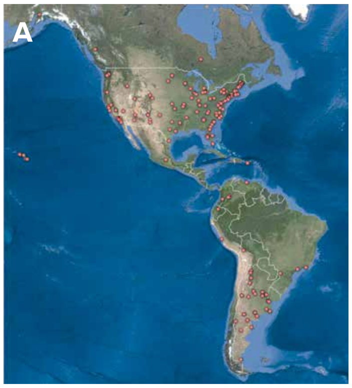
Each of the 11 webinars included post-event evaluation using online surveys. Consistent with findings from previous work (deCharon et al., 2013; deCharon, 2014), participants in these webinars strongly supported the efficacy of concept-map-based presentations in clearly communicating complex ocean sciences research. The majority of participants (55.6%) who completed post-event surveys for SPURS webinars (n = 90) agreed that they were likely to use the concept maps in their work.

The SPURS webinars also provided opportunities to get feedback on deconstructed visual materials. Over 60% of participants who provided open-ended comments on the "most effective aspect" of the webinars (n = 81) mentioned "visuals," "images," or "diagrams," including:

- *I loved the updated water cycle diagram. I'll be using it in class.*
- *Various visuals—many I could definitely use with my 6th grade students.*
- *Great descriptions and visuals of the instruments.*
- *Images of the variety of instruments that are being used to study the ocean and how and where they are deployed. I was amazed at the number of Argo floats in the ocean!*
- *Pictures of [the] process of launching [a] buoy, schematics and talk about the logistics and engineering considerations.*
- *Helpful pictures and explanations about the various pieces of equipment on the buoys.*

Participants in the SPURS webinars were surveyed on their potential application of the science content, which 82.4% (n = 91) agreed that they were likely to use. At the conclusion of each event, they were also asked to assess their change in comfort level, if any, with a common set of six statements, which were adapted from literacy documents (e.g., NRC, 2012; NOAA, 2013):

1. New technologies can affect society and the environment, including in ways that were not anticipated.
2. Scientific discoveries about the natural world can often lead to new and improved technologies, which are developed through the engineering design process.
3. Models of oceanic and atmospheric circulation are used to construct explanations for the development of regional climates.



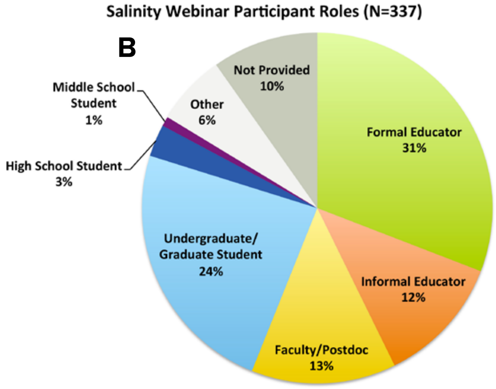


Figure 3. Webinar participants (n = 337 unique individuals). (A) By location. Greece, Italy, and the United Kingdom are not shown. (B) By stated role.

4. Unequal heating of Earth's surface and its rotation result in patterns of atmospheric and oceanic circulation that vary with latitude, altitude, and land distribution.
5. Physical and chemical properties of water affect the flow of energy and the cycling of matter within and among Earth systems.
6. Changes in temperature and salinity cause changes in ocean water density and as a result, affect the formation and movement of interconnected ocean currents.

The SPURS webinars were evenly divided into two series: the first focused on background information, technology, and models while the second addressed ocean-atmosphere exchanges and cycles (Table 1). The percentage of participants who were "More Comfortable" with statements #1 through #6 (above) varied based on the specific topics covered in each webinar presentation. However, for all webinars, at least 26% of participants (11<n<20) stated they were "more comfortable" with each of the six topics.

The highest gains in participants' comfort levels with statements #1 (69.2%; n = 13), #2 (84.6%; n = 13), and #3 (63.6%; n = 11) occurred during the first webinar series, which featured Eric Lindstrom (NASA), Ray Schmitt (WHOI), and Fred Bingham (University of North Carolina Wilmington). The highest gains in participants' comfort levels with statements #4 (70.0%; n = 20) and #5 (75.0%; n = 12) occurred during the second series, which featured Julius Busecke (Columbia University), Stephen Riser (University of Washington), and Tom Farrar (WHOI). The highest gain in comfort level with statement #6 was equivalent (75.0%) for Schmitt's and Busecke's webinars (n = 20 for each).

Unlike the more closely spaced SPURS webinars, the Aquarius webinars in this study were conducted over a relatively long time span: the first was held just before the launch of the instrument (May 2011) and the latest event was in November 2013. Another distinguishing factor was that Aquarius webinar presentations were held in both English and Spanish (Table 1). As a result, the survey questions for Aquarius webinars were much more streamlined than SPURS, focusing primarily on their usefulness, applicability, and perceived success with science, technology, engineering, and math (STEM) students. Table 2 summarizes cumulative data from completed post-webinar surveys, attesting to the overall high degree of effectiveness of these events.

"Lessons learned" over years of Aquarius communication and public engagement activities, coupled with diminishing support for in-person events, prompted the strategic decision to transition from exclusively holding concept-mapping workshops to primarily delivering concept-map-based webinar events. As expected, the transition to webinars has greatly increased the number of participants and expanded the geographic reach from local to global. However, an important objective for SPEC was to ensure that science content delivery to webinar participants was on par with the science content delivery to people who attended workshops.

The SPEC team developed a specialized evaluation rubric to collect equivalent data in association with concept-mapping workshops and webinars. It focused on presenters' use of jargon, the clarity of concept maps presented, and the effectiveness of the "take-home messages." Post-event evaluation surveys employed for SPURS webinars used the same rubric that was field tested during previous in-person workshops (deCharon et al., 2013). Figure 4 shows that the webinar presenters had equivalent success in using jargon appropriately (4.5 out of a maximum 5.0). Ratings of the clarity of the concept maps presented during webinars are on par with those presented during in-person workshops (i.e., 4.3 out of a maximum of 5.0). Ratings on the webinar presenters' "take-home messages" are equivalent with the ratings given by the workshops' target audiences (4.1 out of a maximum 5.0). These results are encouraging in terms of significantly increasing the size and geographic breadth of the audience without sacrificing the efficacy of content delivery.

CONCLUSIONS

The scientists, engineers, communications staff, and audiences involved in these webinars recognize the benefits of sharing ocean salinity findings beyond the research community. Deliberately applying critical thinking skills while preparing for and delivering Aquarius and SPURS webinars ensures delivery of high-quality events and products. Deconstruction in various forms, from

TABLE 2. Participant feedback on Aquarius webinars (bottom rows of Table 1).

Statement	Agree or Strongly Agree	n
"This webinar has inspired me to bring NASA content into my classroom."	89.0%	109
"I can immediately apply what I learned from this NASA webinar to my teaching about STEM."	86.9%	107
"I will be more effective in teaching STEM concepts included in this NASA webinar."	88.0%	108
"The NASA materials used in this experience align well with what I teach."	88.9%	108
"These resources will be effective in increasing my students' interest in STEM topics."	92.6%	108
"The webinar provided ideas for encouraging student exploration, discussion and participation."	90.7%	107

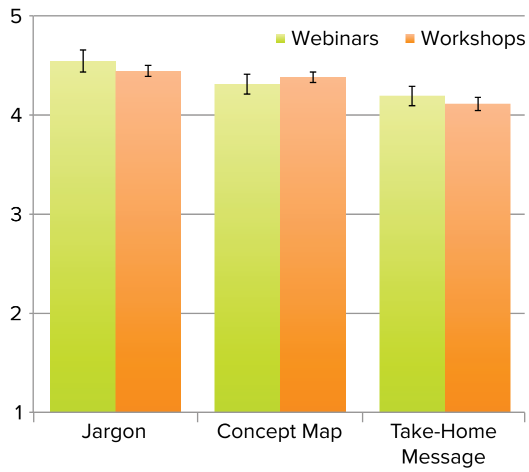


Figure 4. Average feedback ratings on concept map presentations based on a five-point Likert scale for SPURS webinars (green; from left to right n = 98, 100, 98) and previous workshops (orange; from left to right n = 262, 260, 256). Lower values (i.e., 1 or 2) correspond to less effective delivery and higher values (i.e., 4 or 5) correspond to more effective delivery in each presentation category.

mapping out complex science to simplifying visual materials, has proven instrumental in aiding audience understanding of salinity science, technology, and engineering concepts. Classroom educators and their students were given direct access to innovative STEM content, cost-free software, vetted learning resources, and, perhaps most importantly, insights into the critical thinking used by scientists and engineers to solve real-world problems. By transitioning effective communication techniques from workshops to webinars and offering online content in English and Spanish, this science, engineering, and communications team continues to reach broad audiences, enhancing their appreciation of the ocean's role in societally relevant, yet complex issues such as climate change.

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