

Lessons from the Marine Seismic Questionnaire Assessed by the Marcus Langseth Science Oversight Committee:

The survey results show that marine seismic data underpin or are the centerpiece of current research for a large, diverse community - both marine seismologists and non-experts. The range of research areas encompassed by respondents expressing a need for marine seismic data spans nearly the full scope of MG&G science. A need for improved “how-to” information, training and accessible/affordable processing capability is highlighted in the responses- some of this concern can be addressed in the near term, some aspects warrant a longer term effort.

Background:

Between Jun 13th and July 1st, 2016, the UNOLS office conducted a survey of the marine geoscience community to assess priorities for seismic work in their research. One of the primary goals was to assess the size and breadth of the marine seismology community, which collects, processes and interprets the data, and how large and broad the community of “non-specialist” users of the data is. Among other things, the survey was also intended to assess the types of marine seismic data that are in demand and with what priority.

The survey was designed for separate responses from the seismic “specialist” and for “non-specialists” (questions are listed below in Appendix). Consequently, a different subset of questions was asked of these two groups of respondents. Specifically, those who considered themselves “specialists” by answering so in Question 6 were presented with Questions 7-15, skipped Questions 16 – 20, and then were asked Questions 21-40. Those who responded as a “non-specialist” for Question 6, were not presented with Questions 7 – 15 and skipped from Question 6 to Questions 16 – 40. Consequently Questions 7 – 20 appear to have a high number of respondents who skipped many of the questions, which could be incorrectly interpreted as a negative response. In fact, respondents answered nearly all the questions they were presented and the percentages shown in the results should be taken at face value. Also note that Question 7 is the same as Question 19, but Question 7 was answered by “specialists” and Question 19 was answered by “non-specialists”. Similar is true for Questions 15 (“specialists”) and 20 (“non-specialists”).

Who responded:

There were a total of 263 respondents to the survey. Respondents spanned a broad spectrum of the marine geology and geophysics community and appeared to be familiar with the marine seismic situation within the US. Their profiles can be summarized as: nearly all the respondents are from academia or government research, there was < 1% from industry. Most had substantial hard money support for their salary; only ~1/4 raise more than 4 months of their salary per year. The majority (nearly half) are faculty, and about the same proportion are beyond formal education for 20+ years; 51 early career scientists (postdocs or students) responded. Funding for the majority of respondents (> 80%) to conduct seismic data research came from NSF. Consequently we presume that the majority of

respondents were quite familiar with US marine seismics in the academic community. Among the “specialists” (“non-specialists” were not asked), many had also received support from non-NSF sources such as other government funding, industry, and private sources.

One of the most notable results regarding the respondent’s profiles was that such a large number of “non-specialists” responded. There were nearly equal numbers of both groups (“non-specialists” outnumbered “specialists” by one). These are researchers who rely on products from seismic surveys, but do not acquire or work on the seismic data themselves (discussed below). Many stated in their comments that they do not have the background to acquire their own data but are able to access data they need through collaborations. This is noteworthy because it shows the large demand for use of these data beyond the PIs who acquire these data; it illustrates great value added beyond the support for individual projects that carry out seismic acquisition, processing and initial interpretation.

The area of research interest among the respondents was very broad and spanned all areas of active marine seismic studies. This includes deep studies of the lithosphere and mantle to shallow marine sediments/landslides and gas hydrates. The largest area of interest was convergent margins, but an almost equal number of respondents indicated that their primary interest was mid-ocean ridges/rifts/transforms. There was also strong interest in structure/evolution of the lithosphere, sedimentology, and passive margins, as well as marine seismic hazards.

Strong interest in the broader US ocean sciences community for marine seismic data:

One of the most apparent outcomes of the survey is the strong interest in having seismic data of all sorts for marine geology and geophysical studies. The survey generated 263 responses, which we consider to be an excellent response from the community. To put this in perspective, the Virtual Town Hall that solicited input for the decadal survey in 2015 solicited input across the entire spectrum of ocean sciences supported by NSF, and not just the marine seismic community. That survey received ~ 400 responses. We believe the response generated by this survey shows strong endorsement for the marine seismic work supported by the NSF funded ocean sciences program.

Given the large number of respondents who consider themselves “non-specialists”, we believe that this is affirmation of a long-held presumption that marine seismic data is very broadly used by many more than are supported to acquire, process, and advance analysis methods for these data. Of all marine data acquisition, seismic data, unfortunately, has one of the highest barriers to new users in terms of facilities, knowledge and experience for survey design, seismic data processing, and interpretation. Consequently we expect there will always be many who will not acquire and work on the data directly themselves, but will rely on others to provide processed data, interpretations, or other products from seismic results. This emerges from the responses. Among non-specialists, 88% used seismic products in their research. (The seismic specialists were not asked this question because it was presumed that all of them do.) Among all respondent, 94% plan to use seismic data in the future, with a high percentage of them being “non-specialists” (89% within that group), yet the majority of respondents have never submitted a NSF proposal to collect seismic data and 75% have not served as PI or co-PI in the last five years (even fewer have participated in another role on a cruise). Only 60% said

they were likely to submit a proposal to NSF to acquire data in the future. These results are strong affirmation that marine seismic data serve a broad, substantial component of the marine science research in the US, and that there is a large population of “non-specialists” within our community who use these data for their research once they are acquired, processed and made available by the “specialists”.

Broad range of science questions addressed with seismic studies:

The science questions that respondents address is very diverse. Respondents were allowed to put themselves into multiple research interest categories and many of the categories are broadly inclusive while others much narrower. However, among the broad categories of Convergent margins, Mid-Ocean ridges/Active rifts/Transform margins, and Passive margins, Convergent margins (44%) and Mid-Ocean ridges/Active rifts/Transform margins (40%) were nearly equally represented and Passive margins were not far behind (28%). Among the more specialized categories, there was strong interest (34% - 10%) in Mantle dynamics, Structure and evolution of the lithosphere, Sealevel history, Paleo-oceanography, Sedimentology/Sediment stratigraphy/architecture, Gas hydrates and hydrate stability, Submarine hydrology/seeps, Hydrothermal systems, Earthquake processes, Earthquake hazard, Landslides/Mass wasting, Tsunami generation. A surprising number of others responded with interest in volcanology, which was not included as a category. The responses show very clearly that marine seismic data is broadly used and critical to a wide range of current topics in Earth sciences.

Langseth facilities support the community well, but Langseth does not do it all:

The types of seismic data acquisition of most interest to respondents are broad and range from high-resolution, shallow penetration to deep penetration. By far the most demand is for 2D MCS (72%) with hull mounted-chirp (41%) and active source OBS investigation the next highest in demand (39%). This result is not surprising given that these are the types of systems that have been used most over the past several decades. It is clear that most respondents want to continue to have these systems available. What is also evident is that most all of the other systems are needed to meet a broad demand. Passive source OBS deployments (broadband and short period), land seismometers, refraction from non-OBS instrumentation, Towed CHIRP, 3D MCS, 2D long-offset MCS, and portable high-resolution seismic (other than P-cable and CHIRP), all had a very similar number of responses, in the 20-30% range. The only systems that did not have strong interest were the P-Cable (which is relatively new) and Moored hydrophone systems. The individual written responses to Question 29 regarding system demands included a similar broad range of these same systems.

International partnering:

The survey revealed that there is a large amount of marine seismic work that is conducted through partnerships with the international community. The majority of “specialists” (55%; note that this was only asked of the “specialists”) have requested or used data from foreign sources or collaborated with international partners in seismic data acquisition. The number who have collaborated with foreigners on acquisition is surprisingly large and international collaborations are common.

What also stands out from the survey is that international collaborations include an impressive list of countries that span the globe. Countries listed as co-partnering with the US community are (30 in total): Canada, UK, Germany, Turkey, Spain, Costa Rica, Iceland, Norway, Japan, Greece, Ecuador, France, New Zealand, Portugal, Peru, Mexico, Ethiopia, Papua New Guinea, Malawi, Tanzania, Indonesia, Poland, Russia, Denmark, Australia, Italy, South Africa, Israel, Brazil, Taiwan, and China. All of the main international marine seismic players are included in this list, as well as many who are less mainstream in the global marine seismic community.

Barriers:

The survey revealed several interesting results regarding some of the reasons why more of the marine seismic community is not actively involved in data acquisition. There does not seem to be any issue with understanding how to get access to seismic facilities. Almost $\frac{3}{4}$ of the respondents (only “specialists” were asked) answered that they knew how to access the facilities they need. There were minor issues cited, such as scheduling, and facilities that are seen as barriers; however, 72% (including “specialists” and “non-specialists”) stated that they understood how to obtain access to facilities that they needed. What is evident from the survey is that while there is interest in submitting proposals (60% of all respondents; Q 28), the primary issue for them was funding. Among “specialists” and “non-specialists” combined, 85% cited funding availability as the primary factor that limits the types of science questions they are able to address.

The most commonly cited reason for not serving as a PI on a cruise was the lack of background in seismology or know-how with acquisition, processing and interpretation. This is consistent with the fact that half of the respondents are “non-specialist”. However, there is also some indication from the answer to the question on what would enhance your ability to serve as PI (Q35), that there is interest in improving ways to become a PI on marine seismic cruises. Lack of funding/ship time was cited as a large obstacle. One of the most concerning is the indication that the community is insular, which appeared in some of the comments (although not necessarily from more than one person). Other suggestions for improving access range from better networking with current PIs, more information on the proposal/permitting processes, training and facilities for seismic data processing, training cruises, and certainly more funding.

Aging community:

One of the most apparent observations from this survey is that the US marine seismic community is mostly senior scientists and there are few early career scientists filling in behind them. As mentioned above, the majority of respondents are senior scientists, 20+ years from their formal education. While “non-specialists” have a small number of students working on seismic data for research (32%), surprisingly that number is only 60% among the “specialists”. Unfortunately there was not a question asking for the reasons why this is the case. In any case, it is apparent from the responses that the community is aging and does not have sufficient early career replacements.

Outreach opportunities and outstanding issues:

Throughout the survey's written responses, there were a number of issues and opportunities that emerged. Here are some of the most apparent ones that are also the most addressable:

- 1) Training workshops for data access/facilities/processing/interpretation.
- 2) Webinars to provide a "how-to" for breaking into the seismic data acquisition.
- 3) Developing strategies to become less insular, allowing potential growth in the number of seismic users.
- 4) Cruises and on-board training for early career scientists.

Other notable issues raised, but harder to address:

- 1) More funds for processing
- 2) More facilities for processing
- 3) More funding for Langseth
- 4) Upgrades/restructuring for OBS facilities

Survey Summary:

The survey was conducted to address several specific questions regarding community size, breadth among "specialists" and "non-specialists", instrumentation and methods needed for the future, and the future directions of marine seismic studies.

The results for the survey show strong needs for marine seismic data from a large, diverse community of both "specialists" and "non-specialist". Funding for marine seismic acquisition, processing and interpretation are highly leveraged with use by a large community of "non-specialists".

The current capabilities on the *R/V Langseth* provide the tools needed to conduct the majority of work that US marine seismic community needs. The ability to acquire 2D, 3D, and long-streamer 2D MCS, multibeam, and the ability to deploy OBSs along with the ability to provide the seismic source for active source OBS acquisition, satisfies the majority of the needs for this community. However, Langseth alone cannot support the community needs globally at any one time.

The future demand for marine seismic studies will continue to follow the current interests expressed in the survey. Future marine science interests span a broad range of cutting edge topics in a wide variety of tectonic settings. Topics range from fundamental, crustal scale processes to marine seismic hazards and much in between, all of which are at the cutting edge of modern marine science research and are exciting science for NSF science programs.

How a Marine Seismic Oversight Committee could help:

- Identify geographic regions where coordinated marine seismic (possibly other) asset use could enable integrated research or unique new, or next-level, insight into Earth or Ocean processes.
- Recommend geographic regions for near-term (3-5 yr) NSF ship/equipment experiments and explain why this timing would be beneficial.
- Provide advice on developing interests for future (5-8 yr) region focus.
- Gather advice on technical needs for OBSIP, Langseth and high-resolution seismic assets and determine whether there is consensus on prioritization amongst currently desired improvements
- Direct PIs with questions on marine seismic asset use to appropriate contact(s)
- Develop mechanisms for improved marine seismic training
 - berth provision on research cruises
 - regular (series) webinars on various aspects of data access, processing, interpretation guidance
 - consider different models for access to processing capability (and advise NSF when possible)
 - 2-4 national processing centers with well-equipped facilities where researchers spend some weeks during their project, and where regular training sessions for new users and more advanced users are scheduled throughout the year.
 - Encourage all marine seismic proponents to participate in training activities, webinars, berth opportunities, as (a component of) their Broader Impacts for proposals
- Identify topics where different subfields could benefit from cross training/info exchange & suggest mechanisms to achieve this, for example:
 - experiment design & planning
 - seismic data processing/analysis and integration of results that use complementary techniques
 - pre-experiment clearances: environmental, margin security, foreign waters, ITAR
 - integrated analysis & model testing using multiple types of constraint
 - interdisciplinary opportunities (e.g. seismics to understand oceanography)
- Advocate for marine seismic research within the broader geoscience community; enunciate and clarify how offshore seismology can achieve outcomes not possible with well-established, onshore seismic efforts; occasionally, provide an alternate perspective to well-established IRIS efforts.

Appendix

Survey Questions

Q1 - How many years has it been since you've completed your formal education?

Q2 - What is your present position within your institution?

Q3 - Please select the organizational type that most closely corresponds to your organization.

Q4 - Do you have to raise more than four months of salary per year?

Q5 - What is the primary focus of your area of research? (select all that apply)

Q6 - Please indicate your specialty below: "specialist" or "non-specialist"

For "specialists only"

Q7 - Do you plan to use seismic data in the future?

Q8 - What is the source of funding for your research using seismic data? (select all that apply)

Q9 - Are you familiar with where to find and how to obtain archived seismic data?

Q10 - What data archives have you used?

Q11 - Have you requested or used seismic data collected by groups outside of the U.S.?

Q12 - Have you collaborated with international partners in collecting seismic data?

Q13 - If you have collaborated with international partners, what countries were your partners from and what types of data did you collect?

Q14 - Briefly describe the science questions you have addressed using seismic data.

Q15 - Do you have students working on seismic data for research?

For "non-specialists" only

Q16 - What is your area of expertise?

Q17 - Have you made use of the products of seismic research in your own research?

Q18 - Please describe how you have used these data/products.

Q19 - Do you plan to use seismic data in the future?

Q20 - Do you have students working on seismic data for research?

For both "specialists" and "non-specialists"

Q21 - Have you ever submitted a proposal through NSF to collect seismic data?

Q22 - What types of seismic facilities/instruments have you used? (select all that apply)

Q23 - Were the seismic data collected used as the primary or secondary data set to address your science questions?

Q24 - How many times in the last 5 years have you served as PI or Co-PI on a seismic cruise funded by NSF?

Q25 - How many times in the last 5 years have you participated (in a role other than PI/Co-PI) in a seismic cruise funded by NSF?

Q26 - How many times in the last 5 years have you served as a PI or Co-PI on a seismic cruise funded by a non-NSF funding source?

- Q27 - How many times in the last 5 years have you participated (in a role other than PI/Co-PI) in a seismic cruise funded by a non-NSF funding source?
- Q28 - Are you likely to submit a proposal to NSF for future seismic data collection?
- Q29 - If you will submit a proposal, what types of seismic data will you collect?
- Q30 - If you will not submit a proposal, what is the primary reason?
- Q31 - Do you understand how to obtain access to the seismic facilities you require?
- Q32 - Do you understand how the costs of using the facilities/instruments are estimated and how they get included in a proposal to NSF?
- Q33 - What primary factor limits the type of science questions you are able to address today using seismic data?
- Q34 - If you have not served as a PI on a seismic cruise and do not plan to, please briefly describe why.
- Q35 - If you have not served as a PI on a seismic cruise but would like to, please briefly describe what new efforts or infrastructure would enhance your ability to serve as a PI on a seismic cruise.
- Q36 - If you have served as a PI on a seismic cruise please describe your experience (for example, Was it successful? What could have made it better?, etc.)
- Q37 - What types of seismic facilities will be required to address critical science questions in the future?
- Q38 - What types of training or other efforts would enhance your ability to use existing data, collect new data, or otherwise increase you access to seismic data?
- Q39 - Are improvements to current capabilities needed now, and what capabilities need to be developed?
- Q40 - Any additional comments?