Eos

Envisioning a Near-Surface Geophysics Center for Convergent Science

A recent effort identified how a proposed near-surface geophysics center integrating research and teaching could address critical challenges and promote community engagement and cultural change.

By **Xavier Comas**, **Sarah Kruse**, **Gordon Grant**, **Brooks Hanson,** and **Laura Lyon**
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Students from Florida Atlantic University conduct a ground-penetrating radar survey in June 2018 along the Rio Blanco in El Yunque National Forest, Puerto Rico. Credit: Xavier Comas

Earth's near-surface environment, which extends from the ground surface to a depth of several kilometers, is but a small fraction of the planet. Yet its importance cannot be overstated for all of us who call it home. This region hosts most of the rock, mineral, soil, groundwater, ice, and surface water resources we use daily and is where the effects of serious natural hazards like earthquakes, volcanic eruptions, floods, and landslides are concentrated.

Critical processes in the near-surface zone operate at all scales, from **microbe-mineral interactions** to **groundwater flow and solute transport** to the **movements of faults and tectonic plates**. Understanding these processes is central to using vital resources sustainably, safeguarding ourselves against natural hazards, and addressing other critical scientific and societal challenges in the 21st century, such as soil and water pollution, energy transitions, and the effects of climate change. Yet because this region is mostly underground, the dynamics, fluxes, and pathways of, for example, water, magma, and carbon are largely cryptic and must be probed or sensed using a variety of geophysical methods.

The crosscutting discipline of **near-surface geophysics** (NSG) is the gateway for understanding this cryptic environment. In size, scope, and impact, NSG has been growing extensively over the past 2–3 decades, thanks to the emergence of many new techniques, methods, and data sets on local to global scales. Together these innovations are providing richer, more efficient, and more detailed views of the subsurface. NSG is now positioned to provide important advances in our understanding of key elements of this environment that sustain and constrain life, much as remote sensing methods have transformed our knowledge of Earth's surface.

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Against this backdrop, in May 2020, the National Academies of Sciences, Engineering, and Medicine (NASEM) delivered a report to the National Science Foundation (NSF) that provided recommendations for addressing 12 priority research questions over the next decade [***National Academies of Sciences, Engineering, and Medicine***, 2020]. Among the recommendations was that NSF should fund a national NSG research center. The recommendation was made because near-surface imaging has become an essential tool for many Earth science fields and because such a center would enable novel observations and insights bearing on many of the priorities highlighted in the report, including questions related to volcanism, seismology, geohazards, hydrogeophysics, biogeophysics, the critical zone, and climate change.

NSF subsequently asked AGU to convene communities of NSG scientists to further explore and report on the need for and value of a potential NSG center. Here we highlight key aspects and results of this exploratory effort.

Earth in Time

The NASEM report, titled *A Vision for NSF Earth Sciences 2020–2030: Earth in Time*, was intended to guide the NSF **Earth Sciences division**'s research programs to address the priority questions identified. Some of these questions are directly relevant to the interests of the NSG community. For example, how is Earth's water cycle changing? How does the critical zone influence climate? How can Earth science research reduce the risk and toll of geohazards? In alignment with the recommendation to create an NSG center, the report also recommended implementing a continental critical zone initiative to develop and deploy a major mapping campaign to characterize the subsurface critical zone over large areas.

NSF currently funds a range of Earth science facilities and consortia. Those most closely associated with near-surface studies include the Seismological Facility for the Advancement of Geoscience (**SAGE**) and the Geodetic Facility for the Advancement of Geoscience (**GAGE**; both operated by the EarthScope Consortium), the National Center for Airborne Laser Mapping (**NCALM**), the Center for Transformative Environmental Monitoring Programs (**CTEMPs**), and the Consortium of Universities for the Advancement of Hydrologic Science Inc. (**CUAHSI**).

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None of these institutions, in their missions or research portfolios, spans the full breadth of NSG science, methods, or applications, hence the call to establish a broader, more integrative center focused on **convergent science**—one of the “**10 Big Ideas**” NSF proposed in 2017—that merges approaches and tools from diverse fields to stimulate discovery.

NSF's request to AGU to explore the recommendation for an NSG center followed two other recent requests by the agency to several science societies asking for input on addressing convergent science related to climate change solutions and geohealth. Responding to those prompts, AGU engaged its member communities to produce reports and recommendations around those topics [*Hanson et al.*, **2021**, **2022a**]. Recently, AGU also **proposed** that NSF create a **Convergence Accelerator** track for community science and climate resilience [***Pandya et al.***, 2023].

All of these reports highlight the growing needs for integration and broader coordination across the sciences; new ways of organizing, funding, and fostering science; and new approaches to science education and connecting communities with science to meet grand challenges facing society (Figure 1). An NSG center could serve as a test bed for implementing and evaluating strategies to address these needs while simultaneously accelerating work on priority questions identified in the *Earth in Time* report.

Gathering Community Input

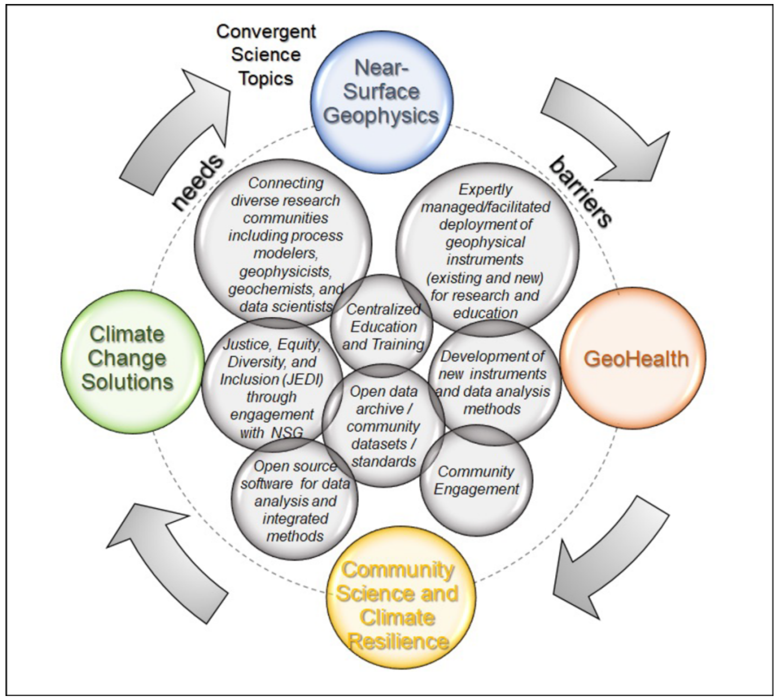

Fig. 1. Near-surface geophysics is connected to many other disciplines and critical societal issues. A near-surface geophysics center could enable convergent work on these challenges and help overcome key barriers inhibiting broader applications. Click image for larger version.

To assess the high-priority science and broader impacts that could be advanced through an NSG center (the scope of which was not defined or constrained) and provide guidance to NSF, we developed a large, structured community engagement and ideation process [***Hanson et al.***, 2022b]. This process was guided by a 12-member steering committee representing diverse expertise in NSG applications and Earth science education. Committee members spanned from early-career to established senior scientists and had extensive experience working in both academia and government agencies and with research consortia such as CUAHSI and the Incorporated Research Institutions for Seismology (IRIS).

The committee distributed a 37-question survey to AGU and Society of Exploration Geophysicists (SEG) members working in NSG. These members responded about education needs in NSG, their awareness of current methods and techniques, impediments to addressing research priorities, and how to improve inclusivity and accessibility in the discipline. Results from 769 responses to this survey were used as the initial input for a series of three virtual workshops held in March and April 2022 that gathered 177 participants.

The survey and workshops had four main goals:

1. Define high-priority science questions aligned with the *Earth in Time* report that require access to integrated NSG instrumentation and expertise or advances in instrumentation or methodology.

2. Identify bottlenecks or gaps in current science infrastructure that impede such studies.

3. Identify impediments to recruitment and retention of students into NSG from 2-year colleges and institutions serving underrepresented students.

4. Envision capabilities of a national NSG center that would support efforts to answer high-priority questions; reduce the impediments identified; and enhance justice, equity, diversity, and inclusivity (JEDI) in NSG.

Output from one event was used as input for the next. In the first workshop, participants condensed 780 open-ended science questions identified by respondents to the initial survey into 24 key science questions. In the second workshop, participants focused on 13 representative key science questions and identified hundreds of related barriers, needs, and potential solutions. Finally, in the third workshop, attendees defined eight integrated opportunities from those needs and solutions, and these opportunities informed the effort's final recommendations to NSF.

Barriers and Opportunities

> *The 13 key questions selected illustrate the breadth and impact of NSG and the need for an integrative approach to advance science and address societal challenges while preparing the science workforce for the future.*

The 13 key questions selected illustrate the breadth and impact of NSG and the need for an integrative approach to advance science and address societal challenges while preparing the science workforce for the future. These questions include, for example, how NSG as a field can enable new discoveries about past land use and archaeological sites, help to manage ground and water resources globally, improve understanding of earthquake effects, characterize processes and fluxes in the critical zone, and expand diversity in the Earth sciences.

Major challenges common in NSG research include the acquisition of spatially rich data sets and real-time monitoring to improve the spatiotemporal resolution and prediction of processes, better quantifying the environmental and community effects of these processes, and using this knowledge to advance progress toward JEDI. In addition to these challenges, workshop discussions revealed other major barriers that hinder deployment of NSG widely and effectively, along with needs to help overcome barriers (Figure 1). These needs include the following:

1. Connecting different research communities—including process modelers, geophysicists, geochemists, and data scientists—both to raise awareness of NSG's versatility and to foster deep interdisciplinary collaborations.

2. Expertly managed and facilitated deployment of a broad pool of geophysical instruments to support research by geophysicists and allied communities and to provide education about, training on, and best practices for the instruments' use.

3. Centralized educational infrastructure, pedagogies, and expertise that would supplement geophysics expertise at institutions and enable different research communities and user groups to participate in NSG more equitably.

4. Improving JEDI in NSG by establishing research partnerships with local stakeholders to enable coproduction and application of science in traditionally underserved communities and by advancing training opportunities to engage a broader range of potential practitioners.

5. Development and deployment of new instruments and data analysis methods to improve multiscale subsurface monitoring and generate information that is not obtainable with available technologies.

6. Open data archives housing standardized data that follow **FAIR** (findable, accessible, interoperable, and reusable) guidelines—as well as education, training, and outreach about leading community data practices—to enable interdisciplinary data reuse and combining of data sets and to extend the outreach of data collected.

7. New open-source software for data analysis, integration, and visualization—and for education—that fills gaps in and advances capabilities of existing software to improve the efficiency of scientific studies and encourage students' exposure to and interest in NSG.

8. Community engagement to grow local knowledge and capacity and engender public trust in and understanding of NSG's uses and applications because the discipline directly informs our understanding of major societal challenges such as resilience against hazards and climate change; water, food, and energy security; improving public health; and supporting sustainability.

The importance of addressing the needs stated above strongly reinforces the recommendation in the *Earth in Time* report that NSF should fund an integrative NSG center with a broader scope than exists at current facilities. The community effort during the workshops also produced final recommendations to NSF about overarching attributes and values that an NSG center should embody. These recommendations focus on how a center should create a vibrant community of practice in NSG, push for needed improvement in NSG with respect to JEDI, enable widespread and state-of-the-art NSG education and training, provide access to and promote development of needed NSG equipment, empower NSG data and software, elevate NSG job opportunities, and lead in outreach and public engagement. A more detailed discussion of these recommendations is given by ***Hanson et al.*** [2022b].

Common Themes of Convergence

The recent NSG report is one of four such documents focused on convergent science topics that the Earth science community has provided to NSF in the past 2 years [*Hanson et al.*, **2021**, **2022a**, **2022b**; ***Pandya et al.***, 2023]. Key themes in these reports overlap greatly: Each addresses similar needs and barriers, specifically related to extended monitoring, integrated data and computing resources, expanded education and training, and community engagement. They all also recommend hub or center models for effectively integrating diverse science efforts.

This overlap casts NSG in an ideal position—via an NSG center—as a bridging discipline that can enable discovery science and engage communities and society broadly to converge toward needed solutions. An NSG center could serve as a larger testing ground than is currently available for potential strategies and solutions that, if successful, could then be applied elsewhere. Collectively, these recent efforts around convergent science indicate that approaches to funding, education, organization, rewards, and connections across the Earth sciences must be strengthened and better aligned to address critical 21st century challenges.

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Acknowledgments

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References

Hanson, R. B., et al. (2021), Report to NSF on AGU community recommendations and ideas regarding implementing climate change solutions, *ESS Open Archive*, 10507256.2, **https://doi.org/10.1002/essoar.10507256.2**.

Hanson, R. B., et al. (2022a), AGU report to NSF on accelerating research and impacts in geohealth, *ESS Open Archive*, 10511162.1, **https://doi.org/10.1002/essoar.10511162.1**.

Hanson, R. B., et al. (2022b), Defining research and teaching priorities that could be advanced through a near-surface geophysics center, *ESS Open Archive*, 10512087.1, **https://doi.org/10.1002/essoar.10512087.1**.

National Academies of Sciences, Engineering, and Medicine (2020), *A Vision for NSF Earth Sciences 2020–2030: Earth in Time*, Natl. Acad. Press, Washington, D.C., **https://doi.org/10.17226/25761**.

Pandya, R., et al. (2023), Recommendations for an NSF convergence accelerator track on community science: A community science report of an NSF-funded convergence accelerator workshop facilitated by the American Geophysical Union, *ESS Open Archive*, 167768122.22544063/v1, **https://doi.org/10.22541/essoar.167768122.22544063/v1**.

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