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Moving from interdisciplinary to convergent research across
geoscience and social sciences: challenges and strategiesDonovan Finn¹ , Kyle Mandli² , Anamaria Bukvic³ , Christopher A Davis^{4,*} , Rebecca Haacker⁴ ,
Rebecca E Morss⁴ , Cassandra R O'Lenick⁴ , Olga Wilhelmi⁴ , Gabrielle Wong-Parodi⁵ ,
Alexis A Merdjanoff⁶ and Talea L Mayo⁷ ¹ School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY, United States of America² Applied Physics and Applied Mathematics, Columbia University, New York, NY, United States of America³ Department of Geography, Center for Coastal Studies, Virginia Tech University, Blacksburg, VA, United States of America⁴ National Center for Atmospheric Research, Boulder, CO, United States of America⁵ Department of Earth System Science and Woods Center for the Environment, Stanford University, Stanford, CA, United States of America⁶ School of Global Public Health, New York University, New York, NY, United States of America⁷ Department of Mathematics, Emory University, Atlanta, GA, United States of America

* Author to whom any correspondence should be addressed.

E-mail: cdavis@ucar.edu**Keywords:** convergent research, interdisciplinary research, early-career researchers, climate change

1. Introduction

Many of today's most societally pressing research questions involve complex, interconnected systems that cannot easily be partitioned and studied in isolation without missing important aspects of the whole. Impacts of a changing climate, where environmental, economic, and social components intersect in complex ways, provide new scientific challenges with significant societal implications (McNutt 2022) and add complexity to the already vexing cross-disciplinary challenges posed by hazards and their impacts (Peek *et al* 2020). For example, past policy decisions like infrastructure siting may make communities more vulnerable to hazards and create pervasive and lasting impacts on societal components ranging from livelihoods to physical and mental health. Disciplinary science alone, while essential, has failed to generate effective long-term solutions to emerging societal challenges at the nexus of climate and environmental change. Given the scale and complexity of these topics, even the laudable innovations of collaborative interdisciplinary science, while important and necessary, are clearly insufficient.

Instead, deeply integrative, action-focused science, in other words, convergent science, is more necessary than ever to develop creative solutions for the most vexing geoscientific and social quandaries—like climate change—within a framework that takes seriously their social, economic, and political dimensions. Connecting fundamental research to real-world applications also helps illustrate to the public and policymakers why continued support for

foundational science is so vital to development of new processes, technologies, and solutions. A recent report from the U.S. National Academies of Sciences, Engineering and Medicine concurs, calling for more investment in 'research on complex interconnections and feedbacks between natural and social processes' (National Academies of Sciences, Engineering, and Medicine (NASEM) 2021).

As defined by the National Science Foundation, convergent science has two key characteristics. It is both 'driven by a specific and compelling problem' and employs 'deep integration across disciplines' (www.nsf.gov/pubs/2019/nsf19551/nsf19551.htm). Convergence, then, is strategic and solutions oriented. It must also seek a higher level of intellectual synthesis than simply engaging expertise from multiple fields, utilizing broadly and deeply integrative approaches that effectively transcend disciplinary boundaries (Peek *et al* 2020). Here we specifically focus on convergent science that helps solve complex societal problems by engaging decision-makers' expertise, e.g. through co-produced science (Jagannathan *et al* 2021). While an interdisciplinary orientation is a minimal requirement for conceptualizing a convergent research agenda, we highlight barriers to elevating even the most ambitious and well-intentioned collaborative projects to the level of convergence.

This perspective represents the insights and experiences of collaborators from diverse areas of research expertise, career stages, institutions, and institutional roles, but all with experience in solutions oriented, interdisciplinary, and community-engaged

research. It is also based on the authors' participation in the Early Career Faculty Innovator Program as faculty, researchers, mentors, and program managers. Since 2019 the U.S. National Center for Atmospheric Research (NCAR) has hosted the Innovator Program to advance interdisciplinary and convergence research across the geosciences and social sciences. Faculty and their students from 21 U.S. universities collaborate with NCAR scientists on a broad range of research related to pressing societal issues of climate change and increasing threats from weather hazards with implications for fields like urban planning and policy, public health, emergency management, and engineering (<https://edec.ucar.edu/university-partnerships/innovators>). Below, we identify key barriers and lessons for evolving towards convergence at the intersection of geoscience and social sciences focusing on the unique role of early-career scientists, and offer strategies to improve outcomes, some of which echo the cited literature.

2. Barriers to successful convergent science

Moving from interdisciplinary science—which is now increasingly common in the climate change sphere—toward truly convergent science is critically important, but difficult. Beyond the innate complexities of the research and community engagement itself, other barriers include the time needed to build trusting relationships among diverse research teams and translate unfamiliar concepts, methods, terminology, and values across disciplines. The transition from interdisciplinary to convergent science, perhaps more critically, also requires rethinking how science is valued, supported, and evaluated. Innovator Program participants have encountered a range of these challenges, briefly summarized in a scaffolded fashion with the most fundamental barriers listed first.

Among the most salient and foundational challenges faced by interdisciplinary researchers involves the integration of data into useful forms for interdisciplinary research projects (Palmer *et al* 2016, Morss *et al* 2021). While geophysical data are usually provided with predetermined spatial or temporal resolutions chosen because of computational or data storage constraints, these data may be suboptimal for co-designed research at highly localized scales. Downscaling can make data more useful but the approach is not always reliable (Zhao *et al* 2021). Disparate types of data, such as climate model outputs and socio-demographic data, can also be difficult to integrate within user-focused decision-support tools. But in a convergence context, these become more than just technical challenges. Social science data may also have implicit ethical aspects that must be considered, such as privacy, sovereignty, and bias, for example, involving Indigenous communities (Walter *et al* 2021). Assumptions about data—what it is, how it is collected, and how it is used—add additional

layers of complexity beyond merely the specifics of synthesizing data and speak directly to the inherent difficulty of integrating research participants and methods from different intellectual traditions (Reich and Reich 2006, Davidson 2015).

Graduate education can also present a particular challenge to training the next generation of convergent scholars (Reich and Reich 2006, National Academies of Sciences, Engineering, and Medicine (NASEM) 2014). Graduate programs typically focus on theories and methods of a particular discipline, for pragmatic reasons, while postdoctoral and faculty positions reward applicants with clear specializations and corresponding disciplinary reputations. Building this profile can be complicated for students whose experiences and publications span disciplines. Convergent research also requires a grounding in multiple fields and methodologies, as well as training in managing diverse teams, writing large-scale grants, and engaging with community stakeholders. A handful of interdisciplinary graduate programs notwithstanding, such training is rare, and training on ethical and respectful approaches to community-engaged research lags even further behind.

Convergent research is by definition solutions oriented, often place-based, and co-production is often a central component. But effective partnerships with local stakeholders and communities usually require years or decades to develop (Kueffer *et al* 2012, Reed *et al* 2014, Steger *et al* 2021). The time required for effective relationship building, research, implementation, and assessment often exceeds the span of graduate education, funding cycles, and university tenure clocks (Benson *et al* 2016). This delays promotion opportunities at research institutions by slowing the accumulation of traditional metrics of research productivity.

Evaluation and tenure systems, furthermore, are not typically designed to appropriately recognize convergent work (Benson *et al* 2016, Schuitema and Sintov 2017). Standard metrics, such as citations and publications in disciplinary journals, may undervalue the impact of convergent research products, or in many cases, not even recognize them (e.g. book chapters, other public scholarship). Institutional systems often have priorities that do not align with the needs of community partners and stakeholders. Researchers, particularly those newly attempting to do convergent work, can find themselves trapped between colleagues and administrators who undervalue community-based science, and stakeholders demanding accountability from researchers working in their communities.

3. Strategies for a successful transition

Strategies for moving from interdisciplinary to transdisciplinary and convergent science focus on sustained learning and on dedicating additional time to

build convergent research teams committed to learning new frameworks, terminology, research methods, and tools across disciplines and the science-practice interface (Davidson 2015, Morss *et al* 2021). These relationships may take years to develop. Time must be allotted for incubation of ideas, team familiarization with each other's approaches, and building connections with local stakeholders to facilitate co-production (Lemos *et al* 2018). Facilitated discussions at every stage are critical to minimizing inevitable misunderstandings. However, in any practical setting, research projects will always begin without full mutual understanding among teams. Continual collaborative learning is essential to keep interdisciplinary research groups focused on the convergent character of the science and ongoing bi-directional integration of ideas and data-driven results.

Tools that serve as a basis of common analysis and synthesis of environmental and societal data are foundational to this process (Morss *et al* 2021, Reilly *et al* 2021). Examples relevant to the Innovator Program include Geographic Information Systems (GISs), and community land and hydrological models. Widely used in the social sciences, GIS allows socio-demographic information, further informed by surveys and focus groups, to be combined with geophysical data resulting in integrative research products and visualizations that inform new interdisciplinary scientific inquiries. Often missing is the cross-training of scientists to understand the proper uses, strengths and limitations of tools used in different disciplines, which is essential to achieving methodological convergence (Boehnert *et al* 2016). Furthermore, the role of scientists experienced in research across disciplines is critical for helping less experienced collaborators ask the right questions and identify communication gaps. Often these involve subtleties in terminology, wherein misinterpretation may not manifest until later in the project. Empowering cross-trained researcher partners to share their knowledge and unique perspective can facilitate sustained learning and help prevent such issues.

Addressing the systemic challenges identified in moving from interdisciplinary to convergent research also requires changing institutional practice and culture (Kueffer *et al* 2012, NASEM 2014, Davidson 2015, Schuitema and Sintov 2017, McNutt 2022). The first inroad toward systemic change is raising the profile of convergent research through education of scholars and administrators. While institutions have widely embraced climate change research, it is less clear that they have simultaneously elevated the importance of convergent research in this realm (Irwin *et al* 2018). Articulating how convergent approaches can identify fundamental research directions with clear benefits to constituencies, while improving institutional engagement with communities, especially vulnerable and high-need

communities, may offer a compelling way to demonstrate institutional relevance.

Second, acceleration of convergent research requires intentional mechanisms like the Innovator Program to partially compensate for the time needed to initiate such work. This requires sustained funding, not necessarily through one particular program, but in broader efforts recognizing the importance of convergent work. Emergence of actionable and translational science high on the agendas of funding bodies and intergovernmental agencies signals support for sustained collaborations and expertise in convergence to address vexing problems, especially those facing underserved communities.

Finally, there is an urgent need to build and sustain a network of expertise in convergence. This should involve expanding student opportunities to fully embrace convergent science thinking with guidance from scholars trained in transdisciplinary and engaged approaches. For example, undergraduate research experiences could include multi-year mentoring and frequent interaction with teams of mentors representing different disciplines, facilitated by scientists experienced in convergence. Network building should also emphasize novel ways to connect experienced researchers with each other and elevate the profile of convergent research within scholarly communities. Such initiatives should also remain inclusive of early-career researchers to build sustained interdisciplinary partnerships and launch convergence-focused careers.

4. Conclusion

The NCAR Early Career Faculty Innovator Program provides a useful lens for analyzing and articulating strategies to address the challenges of moving toward convergence research. Even within a program designed explicitly to support convergent work and into which all participants self-selected, these barriers have remained durable. To varying degrees, each Innovator Program faculty member has experienced all of the challenges outlined above. But there is great potential to address the urgent environment-related problems facing society if these barriers can be overcome. Now is the time for an intentional acceleration of convergence as exemplified by deliberate, deep integration of social science with geoscience to advance community-based research necessary for beneficial climate adaptation outcomes. Because such work faces all the difficulties inherent in transdisciplinary science plus the challenges of long-term relationship building with diverse constituencies, acceleration is unlikely without focused action. At the intersection of geoscience and social science, environmental and societal data are currencies for integrating disciplines and promoting the inclusion of communities in decision-relevant science, but using data as a common language requires full attention to its

biases, accessibility, privacy, and sovereignty. Moving from interdisciplinary to convergent research also requires increased visibility, expanded funding, institutional support for career advancement, and a sustained network of convergence expertise. The above actions can encourage participation in this deeply integrative, high-risk work, which also carries potentially very high academic and societal rewards.

Data availability statement

No new data were created or analysed in this study.

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ORCID iDs

Donovan Finn  <https://orcid.org/0000-0003-1331-2858>

Kyle Mandli  <https://orcid.org/0000-0002-8267-5989>

Anamaria Bukvic  <https://orcid.org/0000-0001-7395-5383>

Christopher A Davis  <https://orcid.org/0000-0003-4530-2726>

Rebecca Haacker  <https://orcid.org/0000-0002-6501-8266>

Rebecca E Morss  <https://orcid.org/0000-0001-6267-3436>

Cassandra R O'Lenick  <https://orcid.org/0000-0003-0936-2406>

Olga Wilhelmi  <https://orcid.org/0000-0002-8496-9710>

Gabrielle Wong-Parodi  <https://orcid.org/0000-0001-5207-7489>

Alexis A Merdjanoff  <https://orcid.org/0000-0002-7218-0106>

Talea L Mayo  <https://orcid.org/0000-0002-7921-871X>

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