GeoHealth Perspectives on Integrated, Coordinated, Open, Networked (ICON) Science

M.A. Barnard[1], S.R. Emani[2], S.K. Fortner[3], L. Haygood[4,5], Q. Sun[6], J.L. White-Newsome[7], and B. Zaitchik.[8]

[1]Institute of Marine Sciences, University of North Carolina at Chapel Hill, 3431 Arendell Street, Morehead City, NC 28557 USA
[2]US Department of Agriculture, Agricultural Research Service, 5601 Sunnyside Avenue, Beltsville, Maryland 20705
[3]Science Education Resource Center, 200 Division Street, Carleton College, Northfield, MN 55057, USA
[4]Department of Geosciences, The University of Tulsa, 800 South Tucker Drive, Tulsa, OK 74104
[5]Boone Pickens School of Geology, Oklahoma State University, 105 Noble Research Center, Stillwater, OK 74075
[6]Institute of Surface Earth System Science, School of Earth System Science, Tianjin University, Tianjin 300072, China.
[7]Empowering A Green Environment and Economy, LLC, West Bloomfield, MI 48324
[8]Department of Earth & Planetary Sciences, Johns Hopkins University, Baltimore, MD 21218

Corresponding authors: Sarah K. Fortner, sfortner@carleton.edu; Lauren Haygood, lauren.haygood@okstate.edu

Author's ORCid:

Lauren Haygood:0000-0002-4060-0700
Qingqing Sun: 0000-0001-5445-4727
Sarah Fortner: 0000-0002-7075-1825
Malcolm Barnard: 0000-0003-4192-574X
Jalonne L. White-Newsome: 0000-0002-4726-0534
Benjamin Zaitchik: 0000-0002-0698-0658
Sujata Emani: 0000-0003-1118-8689

Checkboxes used during submission
MAB: Conceptualization; Writing - Original Draft Preparation; Writing-Reviewing & Editing; Visualization
SRE: Conceptualization; Writing - Original Draft Preparation; Writing-Reviewing & Editing
SKF: Conceptualization; Writing - Original Draft Preparation; Writing-Reviewing & Editing; Visualization
LH: Conceptualization; Writing - Original Draft Preparation; Writing-Reviewing & Editing
JLWN: Conceptualization; Writing - Original Draft Preparation; Writing-Reviewing & Editing
QS: Conceptualization; Writing - Original Draft Preparation;
BZ: Writing-Reviewing & Editing

Index Terms:
0200 GeoHealth
6600 Public Issues

0400 Biogeosciences
0315 Biosphere/Atmosphere Interactions
9800 General or Miscellaneous

Key Points:

- We frame challenges and opportunities to advance equity in GeoHealth using ICON (integrated, coordinated, open science, networked).
- There is a need to develop, improve, and scale coordinated and networked efforts that address collaboration and open science.
- Scaling ICON in GeoHealth includes intentional actions that shift power,and follow community expertise to drive equity in science.

Abstract

This article provides a commentary about the state of Integrated, equitable outcomes. GeoHealth research both characterizes and predicts problems at the nexus of earth and human systems like climate change, pollution, and natural hazards. While GeoHealth excels in the area of integrated science, there is a need to improve coordinated and networked efforts to produce open science that is for and with frontline populations that are disproportionately marginalized by environmental injustice or unequal protection from environmental harms and lack of access and meaningful engagement in decision-making for a healthy environment (EPA). GeoHealth practice has the opportunity to advance environmental justice or the "fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income" with respect to how research and collaboration of GeoHealth professionals supports the "development, implementation, and enforcement of environmental laws, regulations, and policies" that produce equal protection from environmental and health hazards and access to the decision-making for a health environment (EPA). Here we highlight barriers and opportunities to apply an equity-centered ICON framework to the field of GeoHealth to advance environmental justice and health equity.

1 Introduction

Integrated, Coordinated, Open + FAIR, Networked (ICON) science aims to enhance synthesis, increase resource efficiency, and create transferable knowledge (Goldman et al. 2021a). This article belongs to a collection of commentaries (Goldman et al. 2021b) spanning geoscience on the state and future of ICON science.

GeoHealth is an emerging research field that strives to build an integrated earth-human systems understanding that is necessary to characterize, quantify, and predict and prevent health challenges (Almada et al., 2017). Human disruption, especially settler colonization of Earth's

natural systems, causes and amplifies health inequities (Whyte, 2018). The abuse of power and profit for few drives inequities felt through extreme events, food and water insecurity, and infectious disease at neighborhood to national scales (Eby and Hess, 2020). When GeoHealth research is centered on equity, it produces the intersectional research, education, and capacity building and policy engagement needed to produce health equity. Designs for health equity must engage collaboration across human diversity, spatial scales, disciplines, and expertise.

Here, we convey how the approaches of ICON may be centered and applied to advance equity in GeoHealth (Figure 1). Race Forward, a national organization that helps institutions take actions toward racial equity defines equity as both an outcome and process. Everyone should have what they need to thrive and those most impacted by inequities must be "meaningfully involved in the creation and implementation" of policies and practices. In GeoHealth, this means centering and resourcing the priorities and leadership of those marginalized by harm at the nexus of the earth-human system.

Figure 1: Achieving Health Equity in GeoHealth

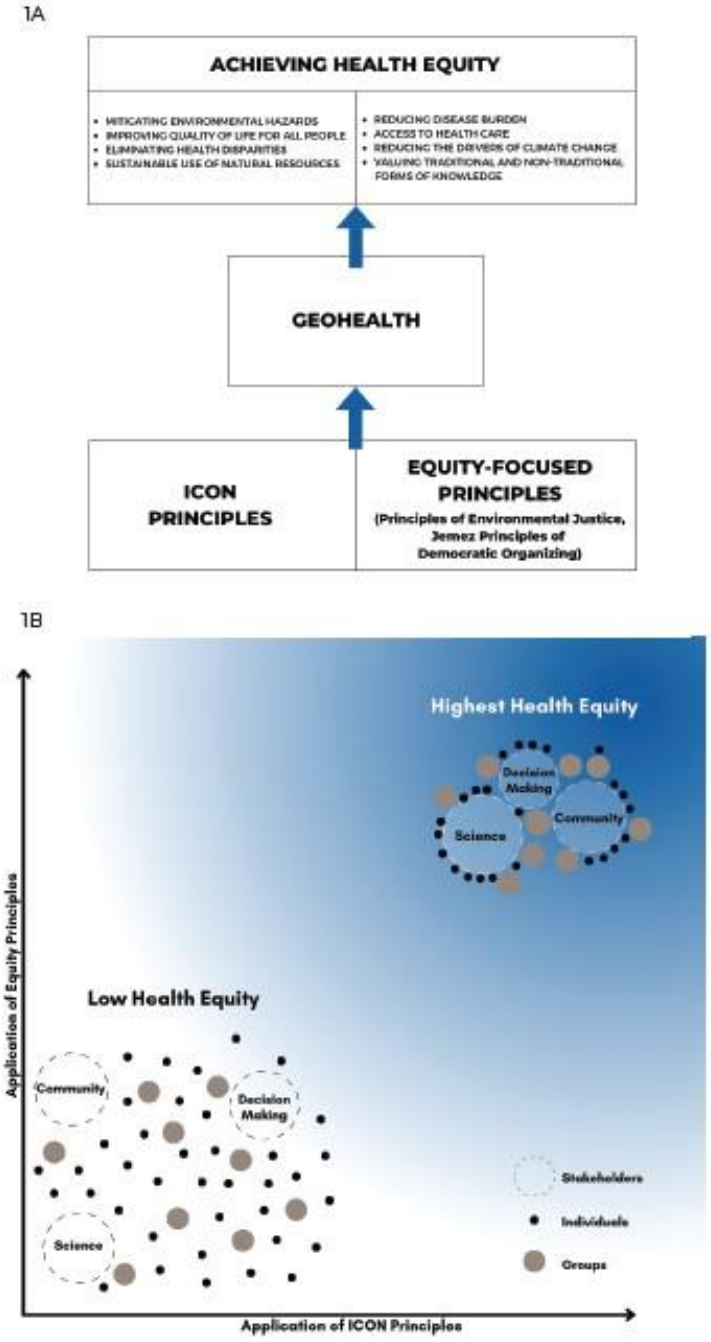

Figure 1A shows the ongoing application of ICON and equity principles to GeoHealth can lead to health equity outcomes. Figure 1B describes how scientists, community members, and decision makers move from low collaborative capacity to produce health equity to high capacity by applying ICON (Integrated, Coordinated, Open-Fair science, Networked) and equity principles.

2 ICON in GeoHealth

2.1 Strengths and challenges

The **integration** of health data, environmental data, demographic, and social data is embedded into GeoHealth research and practice. However, community decision making based on data integration - such as reducing urban heat islands, mitigating flooding, and improving air quality with greening - must be planned with consideration of how they will impact other socioeconomic conditions like gentrification to ensure they are reducing and not producing harm (Eckerd, 2011). Integrated science must span social and environmental systems. **Coordination** of methods and protocols across geopolitical boundaries at all scales advances our real time and predictive understanding of environmental pollution and injustice. Recent work modeling spatial reductions in emissions (e.g. NOx) associated with lockdowns during COVID-19 using international data, highlights the value of coordinating science for more pollutants at the right resolution for scales of action (Sun, 2020). Politics, resource inequities, cost efficiency, funding, data sharing infrastructure, privacy concerns, and even data validity hinder coordination and **Open** Science (Bakker and Ritts, 2018; Beniston et al., 2012). In order to increase the openness of GeoHealth research, research articles and findings should be translated and communicated to the public through both traditional and social media outlets (Pourret et al. 2020; Dwivedi et al. 2021). **Networking** between communities, organizations, and decision makers is also critically important to employ. Collaboration across different expertise and centering frontline community leadership improves predictive and problem-solving capabilities and confronts systemic factors like structural racism, colonialism, capitalism, rural isolation, and political polarization that set up and sustain health inequities. There is a need to move toward community collaboration and employ strategies such as activist-scholar, scholar-activist models that foster community relationships (Reynolds et al. 2020).

2.2 Promising examples of applying ICON to advance equity

At all scales there are exciting examples of collaboration between scientists, community members, community organizations, and decision makers, which demonstrate the potential of ICON principles and practices to support more inclusive and intentional work for equitable and just solutions. Many successful efforts for open science are led and organized by frontline and NGO leadership. For example, Freshwater Future and Earth Economics created and expanded use of the Stormwater Tracking App to empower residents to map stormwater challenges (e.g. upload images of flooding and puddles in their community to inform planning) through **coordination**. Their pilot study engaged North Detroit residents and will expand to empower marginalized communities and protect the Great Lakes. During the COVID-19 pandemic, the team also adapted the app to identify and support families living without water in cities like

Chicago, Detroit, Toledo, Flint, and Benton Harbor. This is an example of equity driving science for health.

Government agencies, organizations, and professional societies, also offer exciting models for ICON across the scientist-community boundary. The European Commission within the EU Science Hub provides a community-science database developed by or with support from the European Commission. Tools are easily accessible, and include a summary of each app or web-based tool. In the United States, there is a similar database found in CitizenScience.gov, where federal crowdsourced and citizen science projects are listed, including their status, project summary, and link to the project webpage. Both databases are user friendly, both in finding data and projects to become involved. Similarly, the EPA's How's My Waterway (HMW) website, provides integrated water data from eight databases within the EPA building networking with community stakeholders to address questions about how communities use and enjoy their waterways. HMW allows users to find information about drinking water, stream conditions, and whether water systems of interest are suitable for fish consumption. Using HMW the Choctaw Nation monitors surface water in southeast Oklahoma and submits their data for open use and public reporting by the state. This example highlights that honoring of Indigenous data sovereignty buildstrust. Similar to the aforementioned examples, The World Health Organization's Urban Health Initiative (UHI) actively supports community building needed for improving health engaging frontline urban leaders in mapping the current decision landscape, then applying environmental and economic tools to their place to educate, mobilize, and sustain efforts to advance change (WHOI, 2021).

Professional societies, non profits, and academic centers who also support the capacity for science in and with communities or with policy makers, are also important to directing the energy and resources of scientists to the advancement of equity through **Networked** science. AGU supports capacity building through the Thriving Earth Exchange which connects community leaders and planners to scientists who help them monitor and evaluate environmental conditions important to community planning. Likewise, Scholars Strategy Network and the Union of Concerned Scientists help scientists find pathways for taking decision relevant science into policy and planning spheres. Similarly, the Environmental Justice Branch of the NAACP coordinates scientists and public audiences across regions to provide resources and science education to leaders of community environmental justice efforts. Collaboration across organizational and cultural boundaries co-creates knowledge and is needed for positive change and scale-up efforts. Working with NOAA, climate scientists and communities impacted by extreme heat and urban flooding, Groundwork USA launched the Climate Safe Neighborhoods Partnership (CSN),(Groundwork USA, 2020). By digitizing and combining historical redlining maps, heat-island locations, and flood vulnerability data, Groundwork Trusts and its partners were able to create shared language for understanding challenges and help move forward equitable policy solutions in the Richmond 300 Master Planning Process, RVA Green 2050 Sustainability Plan, and a Climate Equity Index (White-Newsome and Slay, Forthcoming).

2.3 Future/Recommendations

The advancement of health equity and environmental justice through the practices of GeoHealth calls not only for improving monitoring and forecasting challenges, but intentionally designing education and network building into professional work. We recommend strengthening community education informed by frontline priorities, providing opportunities to K-16 students and early career scientists to build skills in equitable collaboration as part of their education and research mentoring (e.g. Fortner et al., 2021). We also recommend expanding research on the professional development and program designs that develop, improve, and scale collaboration that produces equitable outcomes. Efforts like those of Groundwork USA highlight the value and need to follow the leadership of frontline communities to form science-action partnerships between community organizations, agencies, academics. Scaling-up means active work to shift the value systems and resource distribution in higher education, agencies and organizations as ICON approaches are developed and applied. This includes exploring the outcomes of different levels of sharing and collaboration between scientists and community to enable change. Internationally, there is a need to hold high income countries accountable for network building, monitoring, prediction and solutions technology transfer to under-resourced countries (Suk et al., 2016).

GeoHealth hazards like flooding, air pollution, and extreme heat are widely studied, so international agreements should establish and maintain open data protocols, such as on Protocols.io to increase opportunities for integrated and coordinated efforts. Furthermore, issues like climate change, hazards, and environmental pollution are often tied to who holds political or organizational power, yet impacts are felt most, not by the biggest emitters, but by those least able to respond to increasing floods, heat, infectious disease and more (Ebi et al., 2021). Ultimately, ICON strategies must be designed for scientific understanding and critical engagement that shifts power, policies, practice (Mitchell, 2008) across scales and scientist, community, and decision maker boundaries. As we work toward equitable collaboration, there are opportunities to get started or to improve. We recommend people and organizations begin this journey by first reflecting on key questions as you plan and execute science:

1) What opportunities are there for you to develop a more **integrated** understanding of the GeoHealth issue your work addresses? 2) How will you **coordinate** methods and approaches to advance equity across the science-community boundary? 4) How will you build, leverage, or strengthen **networks** and community participation that support communities most marginalized by GeoHealth Inequities? 5) How will you contribute to equitable **open science** by thinking intentionally about who decides what it is, who contributes it, and how it is made available (FAIR)? 6) How will you advocate for science policy, join or support initiatives that are actively using science to advance environmental equity and justice?

The field of GeoHealth integrated with ICON science, grounded in strong equity principles will help us create the best solutions to address challenges at the interface of health, earth and science.

References

Almada, A. A., Golden, C. D., Osofsky, S. A., & Myers, S. S. (2017). A case for Planetary Health/GeoHealth. *GeoHealth, 1*(2), 75–78. https://doi.org/10.1002/2017gh000084

Barker, K., & Ritts, M. (2018). Smart Earth: A meta-review and implications for environmental governance. *Global Environmental Change, 52,* 201-211. https://doi.org/10.1016/j.gloenvcha.2018.07.011

Boriston, M., Stoffel, M., Harding, R., Kernan, M., Ludwig, R., Moors, E., ... & Tockner, K. (2012). Obstacles to data access for research related to climate and water: implications for science and EU policy-making. *Environmental Science & Policy*, *17,* 41-48. https://doi.org/10.1016/j.envsci.2011.12.002

Chaturvedi, D., Santos, A. L. D., Barnard, M. A., Crimmins, T. M., Malhotra, A., Rod, K. A., et al. (2021). Biogeosciences Perspectives on Integrated, Coordinated, Open, Networked (ICON) Science. Earth and Space Science Open Archive. https:doi.org/10.1002/essoar.10508474.2

Hess, K. L., & Hess, J. J. (2020). Health risks due to climate change: Inequity in causes and consequences: Study examines health risks due to climate change. *Health Affairs, 39(12),* 2056-2062. https://doi.org/10.1377/hlthaff.2020.01125

Kahrl, A. (2011). Cleaning up without clearing out? A spatial assessment of environmental gentrification. *Urban Affairs Review, 47(1),* 31-59. https://doi.org/10.1177/1078087410379720

Martner, S. K., Suffoletta, M. K., Vogt, L. K., Brown, A., & Diaz, M. (2021). An Iterative Course-Based Soil Lead Research and Partnering Model to Address Systemic Racism and the Enduring Legacy of Redlining. *Environmental Justice*. https://doi.org/10.1089/env.2021.0013

Goldman, A.E., Emani, S.R., Pérez-Angel, L.C., Rodríguez-Ramos, Stegen, J.C., Fox, P. 2021a. *Special Collection on Open Collaboration Across Geosciences. EOS. https://eos.org/editors-vox/special-collection-on-open-collaboration-across-geosciences*

Goldman, A. E., Emani, S. R., Pérez-Angel, L. C., Rodríguez-Ramos, J. A., & Stegen, J. C. (2021b). Integrated, coordinated, open, and networked (icon) science to advance the geosciences: Introduction and synthesis of a special collection of commentary articles. Earth and Space Science Open Archive, 22. Retrieved from https://doi.org/10.1002/essoar.10508554.1 doi: 10.1002/essoar.10508554.1

Mitchell, T. D. (2008). Traditional vs. critical service-learning: Engaging the literature to differentiate two models. *Michigan Journal of Community Service Learning,* 14(2), 50-65.

National Academies of Sciences, Engineering, and Medicine, Affairs, P. and G., Information, B. on R. D. and, & Enterprise, C. on T. an O. S. (2018). *Open science by design: Realizing a vision for 21st century research*. National Academies Press.

Perret, O., Suzuki, K. and Takahashi, Y. (2020) Our Study is Published, But the Journey is Not Finished!. *Elements*, 16, 229-230. https://doi.org/10.2138/gselements.16.4.229

Reynolds, K., Block, D. R., Hammelman, C., Jones, B. D., Gilbert, J. L., & Herrera, H. (2020). *Envisioning radical food geographies: Shared learning and praxis through the Food Justice Scholar-Activist/Activist-Scholar Community of Practice.* Human Geography, 13(3), 277–292. https://doi.org/10.1177/1942778620951934

Suk, W. A., Ahanchian, H., Asante, K. A., Carpenter, D. O., Diaz-Barriga, F., Ha, E. H., ... & Landrigan, P. J. (2016). Environmental pollution: an under-recognized threat to children's health,

especially in low-and middle-income countries. *Environmental Health Perspectives, 124(3)*, A41-A45.

Wu, Q.. (2020). The COVID-19 Outbreak Initially Improved Air Quality, Reduced Nitrogen Oxide and Carbon Emissions, and Later Reduced the Incidence of Respiratory Diseases in China. 2020 American Geophysical Union fall meeting. https://agu.confex.com/agu/fm20/meetingapp.cgi/Paper/770736

Urban Environmental Health. (n.d.). Map My Environment. Retrieved September 10, 2021, from https://www.mapmyenvironment.com/

What is Racial Equity? (2021, March 1). Race Forward. https://www.raceforward.org/about/what-is-racial-equity

White-Newsome, J. L., & Slay, J. (2022). Learning to Lead with Equity: Advancing Climate Resilience Planning to Address Urban flooding Across Multiple Sectors and Scales. In B. Petersen &; H. Ducros (Eds.), Justice in Climate Action Planning. Springer.

Whyte, K. (2018). Settler colonialism, ecology, and environmental injustice. Environment and Society, 9(1), 125–144. https://doi.org/10.3167/ares.2018.090109

Acknowledgments

MAB acknowledges funding by the United States National Science Foundation OCE 1840715), the United States National Institutes of Health (NIEHS 1P01ES028939), and a Grant-in-Aid of Research from Sigma Xi, The Scientific Research Society (G201903158412545). SRE acknowledges that this work was supported in part by the U.S. Department of Agriculture, Agricultural Research Service. JLWN acknowledges the support of Modern Media Design for graphic design support for the Figure. Authors declare no financial conflicts of interest.

Author Contributions

SKF framed the outline, merged the writing, finalized the document.. MAB wrote the abstract and the plain language summary. SRE coordinated the team. MAB, SRE, SKF, LH, JLWN, QS: Conceptualization; Original Draft Preparation; SRE, SKF, LH, JLWN, BZ: Reviewing & Editing; MAB, SRE, SKF, JLWN: Visualization.