Ocean Worlds Analog Field Site Assessment: A Report from a Community-led Workshop. H.V. Graham[1], J. C. Stern[1], J.S. Bowman[2], P.T. Doran[3], V.P. Edgcomb[4], K.P. Hand[5], J.F. Holden[6], A.E.G. Howells[7], T.A. Hurford[1], M.J. Malaska[5], E.S. Martin[8], J.A. Mikucki[9], A.C. Noell[5], J. Radebaugh[10], L.E. Rodriguez[5]. [1]NASA Goddard Space Flight Center, 8800 Greenbelt Rd., Greenbelt, MD 20771, heather.v.grhaam@nasa.gov, [2]Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA 92093, [3]Department of Geology and Geophysics, Louisiana State University, Baton Rouge, LA 70802, [4]Department of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, [5]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, [6]Department of Microbiology, University of Massachusetts, Amherst, MA 01003, [7]NASA Ames Research Center, Mountain View, CA 94035, [8]National Air and Space Museum, Smithsonian Institution, Washington, DC 20013, [10]Department of Geological Sciences, Brigham Young University, Provo, UT 84602.

Introduction:

Field research at terrestrial analogs of other worlds provides critical input to our fundamental knowledge of these planetary bodies. We can now study wide-scale planetary processes on Ocean and Icy Worlds and compare them with similar processes on Earth. Our understanding of these planetary processes is built on contributions from oceanographic, cryospheric, geologic, and biologic research conducted by Earth scientists at analog field sites. While planetary scientists approach field work at these sites with different objectives than Earth scientists, there is significant overlap between the two communities that necessitates greater collaboration. There are, however, many obstacles to obtaining funding to perform field research, particularly for Ocean and Icy Worlds, for which many analog field sites are remote and costly to access. The logistical nature of these field sites often restricts their use as analogs to those researchers with the resources and/or professional networks to enable access. Furthermore, because there is no widely accepted set of standards for evaluating the scientific fidelity of Ocean Worlds analog sites, more easily accessed sites are often overlooked as inappropriate analogs, even when they may claim a high level of fidelity to individual aspects of the target body.

To address this need for community-vetted standards for evaluation of the fidelity of analog field sites and their usefulness in modelling the processes and environments on Ocean Worlds, we convened a meeting of both Earth and planetary scientists to discuss and identify important qualities to consider for terrestrial analog field sites. A few approaches were developed to help researchers identify the key features needed for their science question(s) and evaluate potential sites based on the needs of their project. Both the value and the impact of field work at terrestrial analog sites are maximized when the limitations of chosen sites are understood. While there is no perfect analog for every investigation, there are steps an investigator can follow to understand the nature of similarities and recognize trade-offs that may require remediation. Our workshop identified a series of evaluation and presentation techniques to help proposers present their best case for the fidelity of a specific field site to address a high level science question to reviewers.

Workshop Structure and Activities: In order to maintain focus on Ocean Worlds and field work the workshop was limited to 60 participants and included planetary and Earth scientists from diverse fields of geology, chemistry, microbiology, astrobiology, ice physics, and engineering. Participants were selected based on prior field experience at ocean world analog sites and history of Ocean Worlds research. Participants included a broad range of government, academic, and industry institutions including faculty from PUIs (Primarily Undergraduate Institutions). Both in-person and virtual participation was facilitated. Early career researchers made up ~40% of the participants and included graduate students, postdoctoral fellows, agency researchers, and pre-tenure faculty with the balance as mid-career researchers (40%) and senior scientists and engineers (~20%).

To facilitate discussion, the Science Organizing Committee focused on designing activities to develop a field site assessment framework that builds on clear scientific goals and strong arguments to justify field site choices. One effective activity required participants to provide three critical field site criteria for their scientific pursuit that were then grouped and classified as general features during the workshop breakout sessions. The core agenda of the workshop consisted of four keynote presentations designed to provide the background and motivation for Ocean Worlds analog field work and four breakout sessions that analyzed particular sites and science questions in the context of the submitted criteria.

Field Site Assessment Frameworks for Consideration: Through the discussions three methods to assess and present field site fidelity were developed: a narrative questionnaire, a comparative matrix table, and a graphic radar chart. Each of these tools have merits and caveats and can serve to both focus a

scientific question and provide a cross-comparison of proposed field sites.

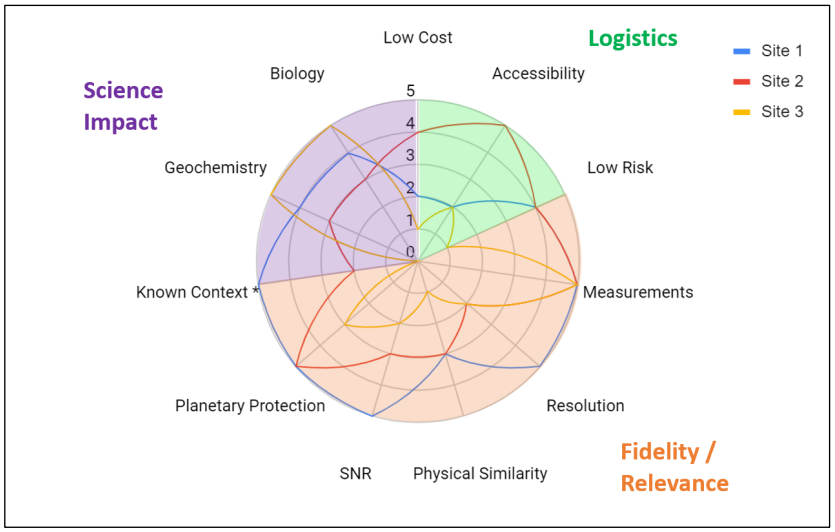
Narrative Approach. This tool expanded on the criteria selection activity and included questions that would step-wise focus the science question into finer detail to identify the key processes and parameters that must be high fidelity at the analog site and which criteria are less important for the proposed research. During the workshop the narrative was applied to a number of "strawman" proposed investigations. The narrative questions are designed to 1) Identify the key process, 2) Identify the necessary parameter(s) and condition(s) that are mimicked by the analog system, 3) Identify the activity (method/process/aspect) leading to innovative research that can be conducted at the site, 4) Identify the necessary signal fidelity needed to address the science question, 5) Identify logistical considerations for sampling and safety, and 6) Identify critical limitations that will need to be mitigated.

Matrix Approach. This tool was designed to provide a tabulated set of field site descriptions with a visual (color) component to aid in rapid comparative value. This tool used the familiar Science Traceability Matrix as a guide. The matrix is organized into four columns with increasing levels of specificity. For example, the Scientific Fidelity column includes both Processes and Environment to distinguish between active processes at a site and the environmental conditions. Similarly, the Logistics column is divided into the Field Operations and Measurements categories which relates to the ability to make a necessary measurement in the field versus the ability to acquire a particular sample. The properties of the field site can be graded as either a strength, a challenge or neutral and include descriptions for these assessment choices.

Visual Aid. Workshop participants designed a graphic that can help communicate the relative merits of potential analog field sites after evaluating with either the *Narrative* or *Matrix* approaches (Figure 1). It is helpful for both developing and proposing a project. In the radar chart different variables or categories drawn are represented quantitatively spanning from a single origin. The surface area or sum of the spoke lengths can be used as a quantitative metric for field site comparison. These scores are subjective but can be developed through the Narrative or Matrix frameworks and the method provides a visual representation of tabulated data.

Summary and Next Steps: The most important outcome of this workshop was the recognition that the fidelity of a field site must be considered within the context of the science question. With a broad range of scientific pursuits represented by our participants – ranging from microbiology to ice rheology – no one field site is likely to accommodate all parameter needs. The Field Site Assessment Framework Tools are designed to 1) help the researcher identify key features, 2) tabulate those needs, and 3) cross-compare potential sites. A detailed Workshop Report is forthcoming that will provide access and instructions for all of the Framework tools developed during the workshop. In addition, a manuscript detailing the outputs of the workshop is in preparation for submission to a peer reviewed journal, with the intent to provide a primer for those proposing field studies for Ocean Worlds analog research.

A frequent workshop discussion topic addressed the fact that the Ocean Worlds community must recognize that many unique locales on Icy and Ocean Worlds present significant challenges in finding valid Earth analog locations. Strategies to recognize and remediate these differences require community effort to apply our knowledge of these systems and agree on how to justify these limitations.



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