SUBSURFACE WATER ICE MAPPING (SWIM) ON MARS TO SUPPORT IN SITU RESOURCE UTILIZATION. N.E. Putzig,[1] G.A. Morgan,[1] Z.M. Bain,[1] D.M.H. Baker,[2] A.M. Bramson,[3] S.W. Courville,[1] C.M. Dundas,[4] R.H. Hoover,[5] D. Hornisher,[1] G.M. Nelson,[1] S. Nerozzi,[3] A. Pathare,[1] M.R. Perry,[1] E.I. Petersen,[2] H.G. Sizemore,[1] B.A. Campbell,[6] M. Mastrogiuseppe,[7] M.T. Mellon,[8] I.B. Smith.[1] [1]Planetary Science Institute, [2]NASA Goddard Space Flight Center, [3]Lunar and Planetary Laboratory, University of Arizona, [4]U.S. Geological Survey, [5]Southwest Research Institute, [6]Smithsonian Institution, [7]Sapienza University of Rome, [8]Cornell University. Contact: nathaniel@putzig.com.

Introduction: The Subsurface Water Ice Mapping (SWIM) project supports an effort by NASA's Mars Exploration Program to assess in situ resource availability for future human missions [1–2]. We are performing global reconnaissance mapping and focused multi-dataset mapping to characterize the distribution of water ice from 60ºS to 60ºN (Fig. 1). In 2019, we produced ice consistency maps for the northern hemisphere (0–60ºN and 0–225ºE, 290–360ºE). In 2020, we are extending our mapping to include the southern hemisphere (0–60ºS) and 225–290ºE in the northern hemisphere at elevations < +1 km. Our maps are being made available on the SWIM Project website (https://swim.psi.edu), and we intend to complete our global mapping by the summer of 2020. Follow us on Twitter @RedPlanetSWIM for project news and product release information.

Motivation: Mid-latitude ice, accessible within the scope of most mission architectures (upper few meters) has been discovered on Mars through remote sensing investigations. For example, fresh impacts revealing icy substrates have been reported using HiRISE data [3–4], and glacial deposits have been found in the mid-latitudes with geomorphologic and radar sounding studies [e.g. 5]. The use of water for fuel generation is a critical component in current human mission scenarios, and thus knowledge of the complete inventory of the distribution and depth range of these water-ice deposits across Mars is of enormous value to planning such missions.

SWIM Project: Our primary goal is to create water-ice mapping products that will inform future mission planning. Prior global studies of Martian ice deposits have largely concentrated on one or two data types, such as neutron maps [6], thermophysical data [7,8], and geomorphic surveys of periglacial features [e.g. 9]. SWIM is unique in seeking to integrate all relevant orbital datasets for a holistic assessment of accessible ice reserves. In addition, our team includes a diverse background of relevant expertise and is leveraging existing and new techniques to generate the most up-to-date maps of Martian water ice distribution.

At the 51st LPSC, we will provide a summary of the SWIM project and present interim results of the latest phase of our ice mapping efforts. These new mapping products will provide valuable tools for

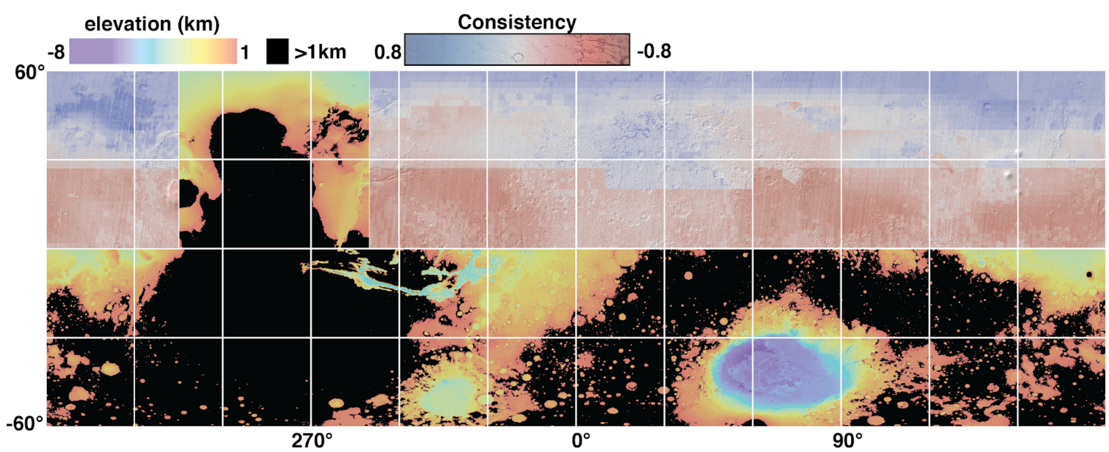

Figure 1. Map of the 2019 SWIM northern hemisphere study area showing water-ice consistency results (blue-red color bar) overlain on an elevation map (rainbow color bar) blacked out at elevations above +1 km to delineate the expanded area added for the 2020 SWIM study.

mission planning activities, and our analysis will highlight limitations of previous and current orbital assets at Mars to advise the next generation of robotic missions needed to fully assess water-ice resources from orbit and in situ.

The SWIM Datasets: To search for and assess the presence of shallow ice across our study regions, the SWIM project uses multiple techniques and datasets: neutron-detected hydrogen (MONS), thermal behavior (TES, THEMIS, and MCS), multiscale geomorphology (HiRISE, CTX, HRSC and MOLA), and surface and subsurface radar echoes (SHARAD) (Fig 2). To extract the maximum amount of information from the data, we are developing new techniques to better delineate water ice within 5 m of the surface, including refined thermal and radar modeling [10-11].

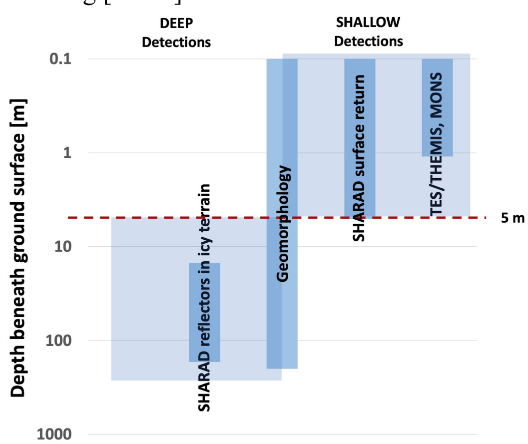

Figure 2. Ranges of approximate resolution depths for each SWIM ice detection technique.

Consistency Mapping: To enable a quantitative assessment of how consistent (or inconsistent) the various datasets are with the presence of buried water ice across our study regions (Fig 1), we introduced the SWIM Equation. For each dataset, we assign consistency values between +1 and -1, where +1 means that the data are consistent with the presence of ice, 0 means that the data give no indications of the presence or absence of ice, and -1 means that the data are inconsistent with the presence of ice. We then calculate an overall value of ice consistency for each map pixel by summing the individual consistency values and normalizing by the number of datasets. In the 2019 study, we chose to apply equal weighting to each input dataset, and thus the current ice consistency values should not be construed to represent a formal probability assessment. For the 2020 work, we are investigating alternatives to improve on this technique. See [12] for more details about our methods. For this presentation, we will provide a summary of our water-ice mapping products derived from integrating all of the datasets and discuss their implications for planning future human and robotic missions.

2019 Study Results: Figure 1 includes our map of composite ice consistency derived from our 2019 multi-dataset analysis, which spanned most of the northern hemisphere of Mars equatorward of 60ºN. The highest consistency values, which are indicative of multiple individual datasets reporting positive (blue) ice signatures, typically occur poleward of ~40ºN—notably in Arcadia Planitia where previous work found indications of widespread ground ice [13] and in Deuteronilus Mensae where others have mapped extensive debris-covered glaciers [14]—but many positive (blue) values extend southward to as low as ~20ºN. In most areas equatorward of 28ºN, the integrated map displays negative (red) values, arguing for ice-free conditions at these low latitudes.

Additional LPSC 51 Presentations: The SWIM team will present a series of posters providing detailed accounts of our mapping methods [12], results from each dataset, and site studies: thermal and neutron analysis [10]; radar surface reflectivity [11]; geomorphology [15]; radar subsurface mapping [16] and in-depth site specific analyses [17].

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