DEMONSTRATION OF PORTABLE TERRESTRIAL COSMIC-RAY NEUTRON SENSORS. N. R. Gonzales[1], C. Hardgrove[1], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287 (nrgonza3@asu.edu).

Introduction: In terrestrial hydrology, there are many *in situ* tools and instruments available to determine the amount of water in the ground. In addition to soil moisture sensors at a range of depths, radial samples of the top 25-30 cm of soil are often used, along with rain gauges. Various correction factors for local vegetation and rock permeability are all known or determined experimentally and are used in combination to determine the water abundance and distribution at depth. More recently, COsmic-ray Soil Moisture Observing System (COSMOS) neutron sensors [1] have been used in terrestrial hydrology with *in situ* samples acquired to complement the neutron data and aid in the interpretation of data (i.e. what neutron moderators other than H are in the soil [1,2]). The use of field-portable passive neutron spectroscopy (PNS) COSMOS sensors have only recently been explored, and understanding both their spatial sensitivity and ability to detect areas of enhanced hydration will be critical for future Artemis surface missions that may carry neutron sensors, as well as future landed rovers and missions that may use these types of instruments. For example, the Curiosity rover carries the first and only neutron sensor, and recent results have shown that neutron counts vary based on surface and subsurface compositions on the scale of just 10 - 30 cm [3], while nearby topography also influences the strength of the neutron signals measured by the detectors [4-6].

For this work we utilize the Jornada Long Term Ecological Research (LTER) facility, which has two COsmic-ray Soil Moisture Observing System (COSMOS) PNS stations [1], one at a small playa, and one in a wash called Tromble Weir [7]. These stations have been used to collect data at both sites since the summer of 2022 and 2010 [7], respectively. We use a new portable COSMOS system (hereafter called RV1 and RV2). RV2 is mounted to a backpack for easy transport. RV1 and 2 are primarily mounted horizontally on tripods, however, RV2 can be used while mounted on the backpacks in the vertical orientation (Fig. 1). All three systems (COSMOS, RV1, and RV2) use a pair of He-3 tubes: one is moderated with polyethylene to slow down neutrons that have not interacted with H (or other moderators) to a speed that will interact with He-3, and the other unmoderated tube counts the number of neutrons that have interacted with other neutron moderators external to the sensor, primarily H [8]. The COSMOS systems also include pressure, humidity, and temperature sensors [9].

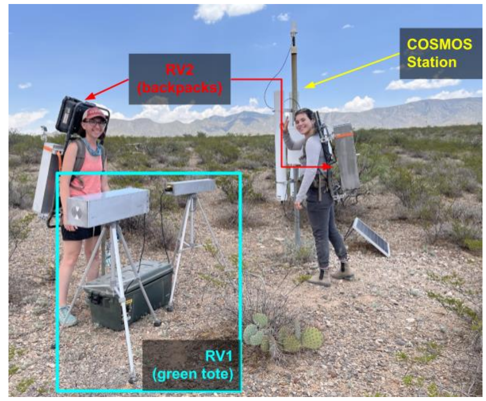

Figure 1. *All three PNS systems are used here. The two horizontally mounted boxes here compose RV1, COSMOS stands vertically on the right side. Both backpacks, worn by author 1 (left) and a member of Dr. Vivoni's team, hold RV2. Note that the tubes on COSMOS are mounted vertically, while RV1 is mounted horizontally, and RV2 is shown stowed vertically. RV2 can be left on the backpacks to be used vertically or mounted on tripods to be used horizontally. All 4 of the sensors for the RV systems are the same length. The COSMOS sensors are 122.5 cm in length [9], RV sensors 56.2 cm.*

Methodology Comparison: To verify what percentage of neutrons detected are from interactions with hydrogen rather than from other neutron moderators in the subsurface, Earth hydrologists take 27-108 samples for calibration [1]. On Earth, hydrologists use the moderated tube as a proxy for soil moisture count, and the unmoderated tube as a proxy for water contained above the ground in the form of snow, vegetation, puddles, and other sources [1]. Terrestrial COSMOS measurements are intended to encompass large footprints, to capture as much of the watershed volume as possible. The detectors are mounted vertically, and their footprint has been simulated to be in the hectares range [7,10], with 86% of the neutrons from ~330m radius [1-2].

The approximate version for instruments like ours in planetary neutron spectroscopy (NS) calculations is to subtract the moderated count rate from the unmoderated to determine how much water equivalent hydrogen (WEH) is <1m below the ground [8].

Before we can use RV1 and 2 systems as a mock planetary PNS, we need to know the footprint and specifications on how it compares to the COSMOS sensor so we can compare the data and verify that we are getting the same results. We began by setting up RV2 on the backpacks, and RV1 set on tripods right next to the COSMOS sensor at the small playa site for several hours. This data showed RV1 and 2 had nearly identical moderated counts, with COSMOS slightly below. The unmoderated counts showed a distinct difference, suggesting a correction for orientation is needed. RV1 had the highest unmoderated counts, followed by RV2, then COSMOS (Fig. 2). RV1 and RV2 measure the same number of counts, verifying they have been calibrated and gain corrected successfully. The differences in counts between the two RV sensor pairs and COSMOS are due to the difference in size between the detector tubes themselves, as well as the gas pressure within the tubes. To compare data between the two systems, a correction factor will likely need to be applied, which is the subject of our current work.

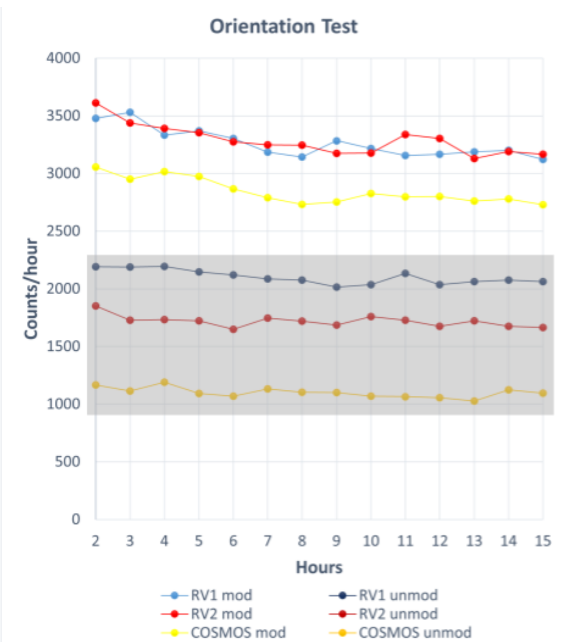

Figure 2. *Orientation Data. RV1 is in blues, RV2 in reds, and COSMOS is in yellows. Note how orientation does not appear to make a difference for the moderated RV sensors (lighter colors), but it does affect the unmoderated sensors (darker colors, in the gray box).*

Then, to test the radial sensitivity of the sensors, we moved the sensors away from the COSMOS small playa station to distances at 100 m increments. As RV1 and 2 stepped farther from the COSMOS station, the count rates of both moderated and unmoderated sensors increased, indicating a decrease in the presence of H and other neutron moderators (Fig. 3) with distance from the central playa. This is consistent with decreased mud/clay content within the sensor field of view at the playa boundary. In addition, increased unmoderated neutron counts outside the playa are consistent with increased surface vegetation. Sparse grass coverage is observed in Fig 3 surrounding the playa with mesquite and creosote spreading outwards [7], and was observed at the field stations, which is consistent with increased surface vegetation around these measurement locations. This preliminary study suggests that the footprint of the RV sensors is less than 300 meters, potentially closer to 50 meters, which would enable neutron measurements at field sites on Earth to investigate geologic features and contacts more readily in preparation for Artemis and CLPS surface missions.

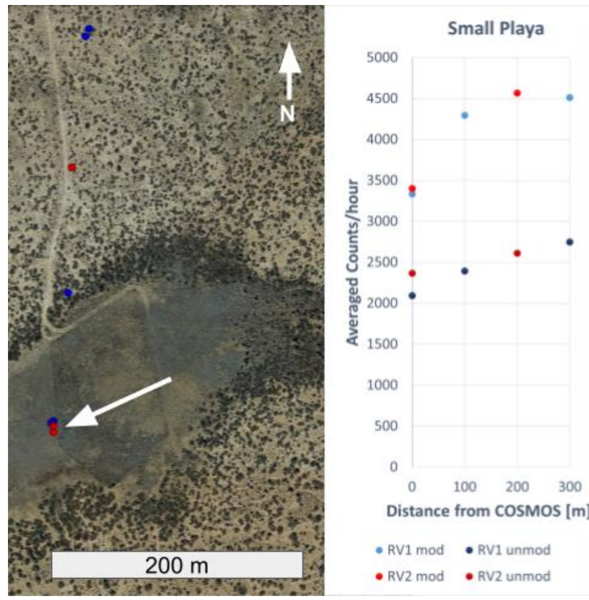

Figure 3. *RV1 and RV2 radial sensitivity test moving northwards from the small playa COSMOS station in 100m increments. In both images, RV1 is in blues, RV2 is in reds. Arrow on the left image indicates COSMOS station. Note the amount of vegetation around the COSMOS station in the left image, indicating there is a higher water concentration within one meter of the surface.*

Future Tests. Future experiments will repeat the traverse experiment from the small playa at the Tromble Weir wash COSMOS station.

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