USING ELECTROSEISMOLOGY TO FIND SUBSURFACE WATER IN OUR SOLAR SYSTEM: AN INITIAL NUMERICAL STUDY. N. J. Roth[1], [1]Pennsylvania State University, PA, USA (nolan.roth@psu.edu)

Introduction: Identification and location of liquid water in the subsurface of planetary and lunar bodies in our solar system is of the utmost importance for the future of astrobiology and space exploration.

Liquid water has been identified previously on Mars (glacial basement lakes [1]) and is theorized on other bodies, such as the icy moons of the solar system. The existence of deep water in the subsurface of Mars or pockets of liquid brine in the shells of our solar system's icy moons remains a mystery.

Traditional methods for liquid water exploration involve seismology or EM sounding. In some cases, however, especially at extreme depths, neither of these methods is unambiguous if relied on alone [2].

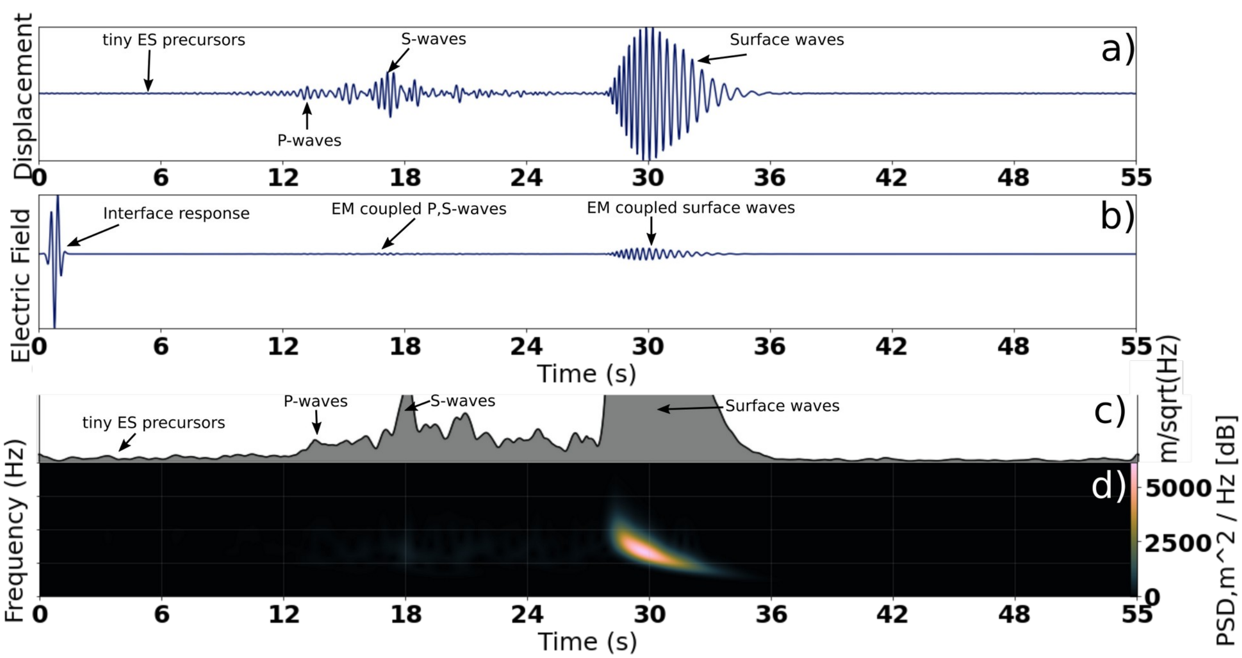
This abstract presents simulations of an exploration method utilizing coupled electro-seismic (ES) wavefields to unambiguously identify liquid water aquifers in the deep subsurface (on the order of 1 km depth). The presented simulation results follow three sources for ES wavefield excitation: passively through deep quakes, passively through nearby impacts or shallow quakes, and actively through electromagnetic pulse and physical ground strikes.

Electroseismology could offer a new avenue for future lander, rover, or crewed space missions to non-invasively probe the subsurface for deep water layers or pockets.

Electro-seismic coupling: Electromagnetic (EM) and seismic waves couple at porous, fluid saturated media interfaces. The coupling phenomena, which is induced at the microscopic level by relative fluid-matrix motion, produces several generally very weak wave types, though the most important is the so-called "interface response" [3]. When a seismic or EM wave impinges on the interface of a saturated porous medium, an independently propagating EM wave is created. This EM wave rapidly travels at the speed of light in the medium, creating identifiable, no-moveout signals in dipole-array setups. This interface response, via the same coupling mechanism, carries a minute seismic energy that may be visible in ultra-sensitive seismometers, such as the SEIS unit on the InSight Mars lander [4]. Because ES coupling only occurs in the presence of a liquid electrolyte, such as water, its usefulness as an exploration technique should be investigated.

Figure below. a) Radial displacement at a receiver placed 50,000m from a surface meteorite impact source. b) Electric field measured at the receiver. Note the ES coupled waves and the strong initial interface response due to a 1km deep saturated aquifer in the model. c) Average spectral power of the displacement trace. Note the increased power prior to the P-waves that is not present after the surface waves, the ES-precursor. d) S-transform of the displacement trace.

Simulated Scenarios: Electroseismic responses could be induced by several sources natural to extraterrestrial bodies such as Mars, Europa, or Enceladus. Quakes and meteor impacts are two sources



shown to be available on Mars [4] and theorized to occur on other solar system bodies at intervals observable to a lander, rover, or crewed mission [5]. Besides these natural sources, active stimulation of the ES response by artificially generated EM pulse or by a physical ground strike are also considered. While some initial models have been run, this section covers primarily expected results from the completion of this work.

Quakes. Quakes are powerful natural sources, producing some of the largest measured ground reactions on Mars during the InSight mission [6]. Because of the inefficient nature of electroseismic coupling, the most attractive candidates for sources are those producing the strongest ground deformations. Thus, shallow quakes producing strong surface waves that penetrate into the depth range of 1-10km could be strong candidates for the excitation of electroseismic interface responses.

Impacts. An example simulation of an impact is shown in the above figure. Impacts, like shallow quakes, can produce large ground deformation and surface waves, as observed by InSight on Mars [6].

Artificial sources. Active source seismology on other planets is a difficult endeavor, though the use of electroseismic techniques could offer a novel avenue. Powerful EM pulses and ground taps near the simulated receiver can teach us about the expected magnitude and detectability of converted ES phases from active sources.

Initial Results: Current limited simulation results predict that for a saturated aquifer 5km below the surface of Mars, the ES interface response created by a impact-induced seismic wave with displacement amplitude of 1 micron at the receiver would have an approximate amplitude of 0.01 V/nm at the receiver. The transverse magnetic converted phase would have an amplitude of around 0.1 pT, far below detectability by an instrument such as InSight's onboard magnetometer [7]. Shallower aquifers are expected to have a larger converted ES phase, though the quantitative aspect of this remains to be studied. Aquifer chemistry may also play a role in ES conversion efficiency.

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