ENHANCED RADAR VISUALIZATION OF STRUCTURE IN THE SOUTH POLAR DEPOSITS OF MARS. B. A. Campbell[1], G. A. Morgan[1], N. E. Putzig[2], J. L. Whitten[1], J. W. Holt[3], and R. J. Phillips[2], [1]Smithsonian Institution, MRC 315, PO Box 37012, Washington, DC 20013-7012, campbellb@si.edu, [2]Southwest Research Institute, 1050 Walnut Street, Suite 300, Boulder, CO 80302, [3]University of Texas, Institute for Geophysics, 10100 Burnet Road, Bldng 196, Austin, TX 78758.

Introduction: SHARAD radar sounding data provide a powerful new perspective on unit mapping for the south polar layered deposits (SPLD) of Mars. We use these observations to investigate the nature of layered reflections and diffuse, “fog-like” echoes from the SPLD. Applying a technique to sum echoes from the overlapping parts of SHARAD tracks leads to significant local enhancement in the detection of subsurface layering. The “fog” likely arises from surface scattering or from an anomalous shallow layer (a few range cells thick) with strong volume scattering properties. In either case, the SPLD near-surface setting is different from that of the NPLD. Perhaps linked to these properties, we find large variations in the layering and behavior of radar echoes with depth across the SPLD.

Nature of the Fog: The SPLD, over large regions, exhibits diffuse or “fog” radar echoes that begin near the surface and persist over delay times greater than the plausible depth of the cap [1]. In the areas of strongest fog, subsurface layering can be much less distinct than in the NPLD [2]. A model that invokes volume scattering over a large depth below the surface is problematic, as pervasive, meter-scale disruption of the cap should also degrade radar-reflecting smooth interfaces. Volume scattering concentrated in a layer just below the surface could account for the observed behavior, but the physical or compositional structures that could cause this seem difficult to sustain over large regions.

Perhaps the simplest explanation is that the “fog” is a surface scattering effect. Its general appearance and delay runout is similar to that of echoes from dune fields such as Olympia Undae, where SHARAD senses reflections from radar-facing dune slopes well away from the nadir track. The strength of the surface return often declines with increasing fog echoes, again similar to the dune-field behaviors. A bright packet structure of radar layering re-appears below trough floors, consistent with the roughness/layer that creates the diffuse echoes not being present in these local lows.

Enhancing Layer Detection: Across the SPLD [3], only the Promethei Lingula deposits have radar-bright subsurface interfaces that are well-resolved in delay over the depth of the unit [4]. This lobe of the cap also hosts reflection-free zones that may comprise additional reservoirs of atmospheric CO_2 [5,6]. The fog echoes are much weaker here than in other parts of the cap, though they can be observed in observations made in a rolled configuration to maximize the signal-to-noise ratio. In most other parts of the cap, particularly closer to the pole, the radar-reflecting interfaces are less evident than in similar views of the NPLD.

We developed a technique to improve layer detection in areas of the SPLD by summing echoes from overlapping SHARAD observations. In practice, we take one track as a base, then locate where any other observation footprint comes within some cutoff distance (e.g., 1 km) of a point along this track. We co-register the echo traces in delay, and keep a running sum of overlapping points. Near the coverage gap at the pole, we can exceed 50 overlapping echo traces, increasing SNR up to 8 dB. The improvement in layer detection is striking in these locales (Fig. 1), and suggests that full 3-d migration of the dataset will yield substantial gains [7].

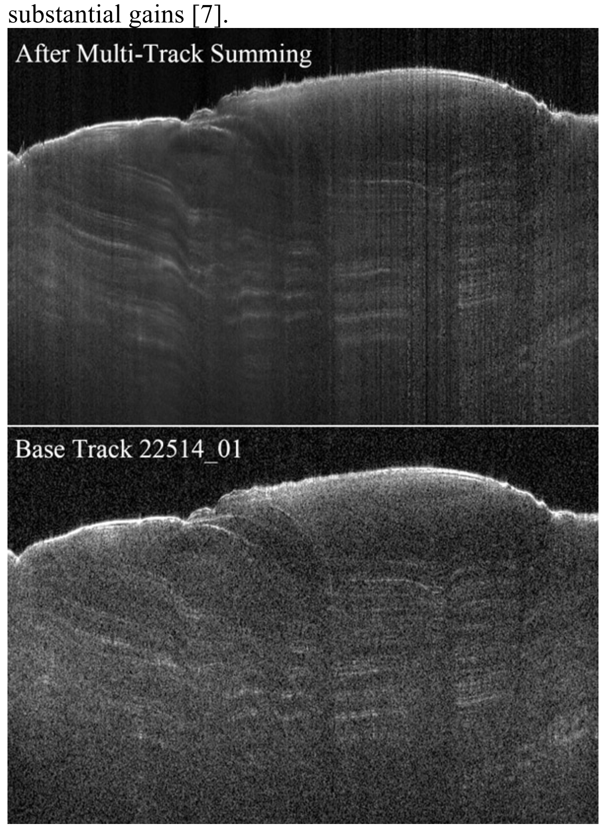

Fig. 1. Portion of SHARAD track 22514_01, a rolled observation of the SPLD. Top shows result of co-adding echo traces from other observations.

This method reveals significant differences within the SPLD in how subsurface interfaces vary in their radar properties with depth. In some sections, such as Promethei Lingula, the radar-detected scattering interfaces resolve as quite narrow features in time delay throughout the thickness of the unit. In other areas, the radar reflections are more spread in time delay, particularly at greater depths below the surface (Fig. 2). One possible explanation is that the high-frequency component of the radar chirp is more strongly attenuated by the SPLD materials than we observe in the northern cap, leading to a degradation in the range compression of the signal and broadening of interfaces in the radargram. This behavior can be seen through processing that breaks the SHARAD chirp bandwidth into "high-frequency" (20-25 MHz) and "low-frequency" (15-20 MHz) channels. For rolled observation 25112_01, we note strong attenuation in high-frequency signals, and a broadening of reflecting interfaces in delay toward greater depth in the low-frequency channel (Fig. 3).

In some tracks, we note a shift of the onset of fog echoes to delay times beyond that of the surface (Fig. 4). The latitude and general properties of the transition do not change from night-time (e.g., 7426_01) to day-time (e.g., 4723_01) SHARAD tracks, from which we infer that this is not a seasonal phenomenon. At the shift from "deep" to "shallow" fog signatures (Fig. 3), the change in surface peak brightness is about 1.5 dB. The presence of the fog-generating layer or interface at depth requires that the depositional or erosional mechanism responsible for it has occurred at multiple times, and that the associated morphology can be preserved by burial. We are working to determine whether the shift in fog echoes correlates with an unconformity in the pattern of radar-detected layering.

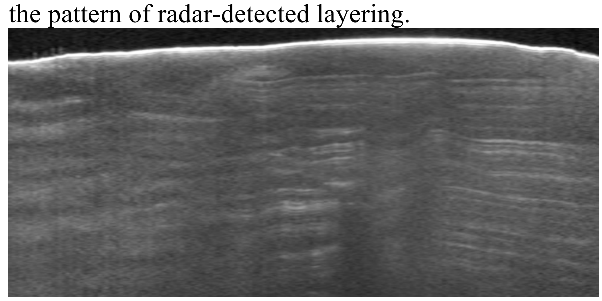

Fig. 2. Portion of SHARAD track 9298_01, enhanced with multi-track method. Delay window ~21 μs. Image about 75 km wide. Note the different patterns of interface reflections over this short span of the SPLD.

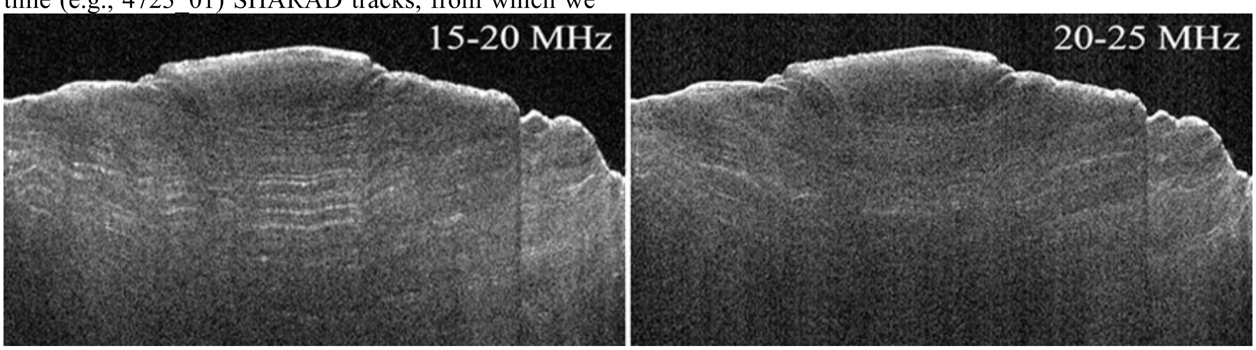

Fig. 3. Portion of SHARAD track 25112_01, processed using a technique that breaks the radar chirp into two channels. Note the greater attenuation of signals in the high frequency channel, and the broadening in delay of reflectors with depth in the low-frequency channel. Images about 425 km across, and ~44 μs in delay range.

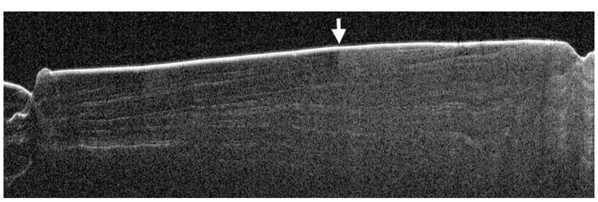

Fig. 4. Portion of SHARAD track 9298_01, showing change in delay location of fog onset with respect to the surface echo (fog signature shifts left of the arrow).

Discussion: The SPLD "fog" echoes likely arise from the near-surface, but the cause of such a major difference from typical NPLD behaviors requires investigation with other remote sensing data and radar models. We are using SHARAD data to assess whether the fog varies on a seasonal basis linked to CO_2 deposition and removal. We are also working with favorably aligned and high-SNR tracks (enhanced with the multi-track technique) to study the lateral extent of layering and the physiographic outlines of particular "fog" and subsurface attenuation patterns. These studies are defining a new subset of units across the SPLD.

References: [1] Campbell B. A., et al., #1350, 8th Int. Conf. on Mars, 2014; [2] Putzig, N.E., et al., *Icarus*, doi:10.1016/j.icarus.2009.07.034, 2009; [3] Tanaka, K.L., et al., USGS Sci. Inv. Map 3292, 2014; [4] Milkovich, S.M., et al., *JGR*, 114, doi:10.1029/2008JE003162, 2009; [5] Phillips, R.J., et al., *Science,* 332,838-841, 2011; [6] Putzig, N.E., et al., this volume, 2015; [7] Putzig, N. E., et al., #1336, 8th Int. Conf. on Mars, 2014.