PROPERTIES OF THE MARS POLAR LAYERED DEPOSITS FROM RADAR SOUNDING. B. A. Campbell[1], G. A. Morgan[1], N. E. Putzig[2], J. W. Holt[3], and R. J. Phillips[3], [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: The north and south polar layered deposits (NPLD and SPLD) of Mars display near-horizontal radar-reflecting interfaces that occur in groups or packets, presumably caused by concentrations of dust or sand that create a contrast in the real dielectric constant with cleaner ice [1, 2]. The specific geological properties of these interfaces remain enigmatic, partly because each radar reflection could arise from single, densely packed sediment layers or a collection of thinner, possibly less concentrated zones. The SPLD also exhibit diffuse or "fog-like" backscatter, of uncertain origin, that can mask other returns. We present a study of radar scattering from the NPLD layering, exploiting the broad bandwidth of the SHARAD observations to investigate their wavelength dependence. We also analyze the spatial variability, scattering behavior, and possible geologic implications of diffuse radar echoes from the SPLD.

NPLD Layer Echoes: The NPLD radar reflections occur in "packets" separated by regions of relatively clean ice accumulation. The individual reflectors may vary in brightness within a packet, and generally become less bright with greater depth due to increasing attenuation and transmission loss through the overlying ice. From the basic SHARAD radargrams (a 2-D presentation of backscattered power with time delay on the vertical axis and along-track position on the horizontal axis), there is no way to discern whether individual reflectors comprise single or multiple, unresolved contributing dielectric layers [2].

The sounder uses a 10-MHz total bandwidth (15-25 MHz), so we can process the raw echoes in at least two sub-band formats: we choose a "low-frequency" (15-20 MHz) and "high-frequency" (20-25 MHz) pairing [3]. The two resulting radargrams have a vertical resolution twice as coarse as the full-bandwidth product, but permit analysis of wavelength dependence in the echoes (the low-frequency component has a free-space center wavelength of 17.1 m, and the high-frequency component center wavelength is 13.3 m). Shifts in the echoes are expected if reflections arise from interference between multiple, closely-spaced dielectric interfaces rather than a single, densely packed dust layer.

Figure 1 shows an example for one track over the NPLD, where the low-frequency component is coded in red, the full-bandwidth product is in green, and the high-frequency component is coded in blue. As expected, the surface echo is relatively uniform with wavelength (white in this mixture), and due to attenuation echoes in the low-frequency component (red) remain stronger, relative to the high-frequency component (blue), with greater depth in the cap. On top of this general trend, reflecting horizons within the NPLD have differences in their color mixture (i.e., wavelength response) that are not explained solely by attenuation due to their different vertical locations. We are working on models to relate these differences to possible thin, packet-like structure within a SHARAD vertical resolution cell [2], and to identify the subset of reflectors that arise from discrete, "thick" layers of packed dust. These latter horizons are candidates for correlations with layer exposures or topographic signatures in trough walls and elsewhere.

SPLD Diffuse Echoes: The SPLD, particularly in the highest southern latitudes, exhibits strong diffuse or "fog" echoes that begin near the surface and persist over delay times greater than the likely depth of the cap itself (Fig. 2). One occasionally noted explanation is volume scattering by sub-wavelength scale fractures or inclusions. Due to the long time delays observed, these echoes could not arise solely along the nadir direction if they are the result of volume scattering; the signals would have to come in large part from either side of the ground track (i.e., diagonally downwards into the PLD).

An alternate hypothesis is that the diffuse echoes arise from rough-surface scattering at an interface within the SPLD. The general appearance and time-delay runout of the "fog" is similar to that of echoes from dune fields such as Olympia Undae, where SHARAD senses strong reflections from radar-facing dune slopes well away from the nadir track [4]. There are clear examples where the diffuse echoes simply stop at a particular point along a sounding track, while horizontal reflectors continue unaffected across the area. It seems unlikely that fractures or inclusions would stop in such an abrupt fashion, whereas a rough horizon could be truncated due to depositional or erosional effects.

We thus propose that most SPLD diffuse returns arise at a rough dielectric interface close (<30-50 m) to the visible surface of the cap. The shallow rough interface may not be widely expressed at the surface itself, as the peak SHARAD echo changes little in traversing the boundary noted in Fig. 2. This suggests that the interface formed due to some geologic or climatic event, then was buried by the growing cap. In some locales, we also see evidence for a second such interface at depth, suggesting that the process leading to their formation and burial has occurred more than once as the PLD developed. Stratigraphically, the shallow "fog-generating" layer lies directly beneath the reflection-free zone mapped in [5] and attributed to massive CO_2 ice deposits. We are investigating whether the inferred rough interfaces may also be linked with major atmospheric collapse events and deposition of CO_2.

References: [1] Seu, R., et al. (2007) JGR, doi:10.1029/2006JE00247, [2] Putzig, N.E., et al. (2009) Icarus, doi:10.1016/j.icarus.2009.07.034, [3] Campbell, B.A., et al. (2013) IEEE GRSL, 11, 632-635, doi:10.1109/LGRS.2013.2273396, [4] Campbell, B.A., et al. (2013), JGR, doi:10.1002/jgre.20050, [5] Phillips, R.J., et al. (2011) Science, doi:101126/science.1203091.

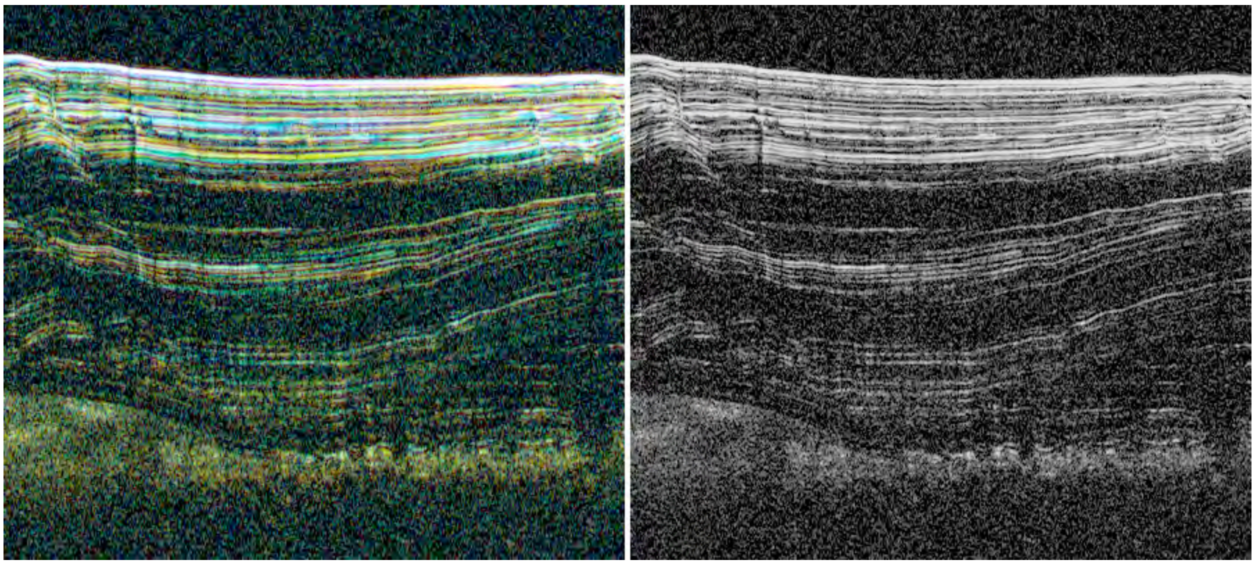

Fig. 1. Portion of SHARAD track 14065_01, showing echoes in 10-MHz image on right, and in a color-coded frequency decomposition on left. Green channel is the 10-MHz product, red channel is low-frequency 5-MHz band, and blue channel is high-frequency 5-MHz band. Image width 207 km; vertical scale 30 μs, or ~2.5 km distance in water ice. Basal unit echoes are reddish-green, consistent with detection primarily by the less attenuated low-frequency signal. Reflecting horizons exhibit a range of color mixtures, suggesting diverse responses to the wavelength of the probing signal.

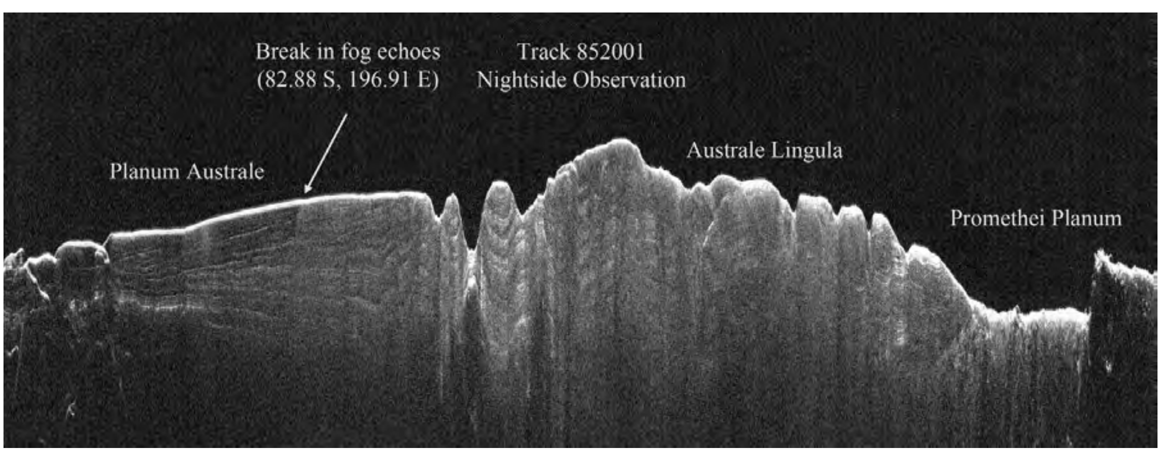

Fig. 2. Portion of SHARAD track 8520_01, collected on the nightside so ionosphere effects are minimal. Note the strong "fog" echo at long delay times below the surface of Australe Lingula, and the abrupt shift in this behavior in Planum Australe. The bright linear reflecting horizons continue across this change in the diffuse scattering behavior. Image width about 730 km; vertical scale 22.5 μs delay time.