First detection of subsurface reflectors in Coprates Chasma, Mars. R. Noguchi[1], K. Ishiyama[1], A. Kumamoto[2], T. Usui[1] and C. Uemura[3] [1]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1, Yoshinodai, Chuo-ku, Sagamihara, Kanagawa, 252-5210 Japan (r-noguchi@planeta.sci.isas.jaxa.jp), [2]Department of Science, Tohoku University, Sendai, Japan, [3]The Graduate University for Advanced Studies (SOKENDAI), Tokyo, Japan.

Introduction: Cryosphere on Mars has been investigated by previous/ongoing missions that have reported dense high-resolution remote sensing datasets. The direct evidence for current cryosphere is the existence of shallow subsurface ice layers [1]. Another feature invoking current icy processes is recurring slope lineae (RSL). RSLs are globally distributed in the mid- and low- latitudes including Valles Marineris [2]. These circumstances imply the pervasive existence of ground ice in shallow depth of current Martian subsurface.

Radar sounding technique has potential to visualize subsurface structure of Mars. This technique has revealed subsurface icy layering [3] and subglacial liquid water [4] beneath the polar caps. However, interpretation of radargram has difficulties for removing clutter echoes and assigning to actual (i.e., observable) layers. Such difficulties could be overcome by studying ideal radargrams that have less clutter echoes and access to assigned subsurface layers, a part of which is exposed on the surface.

Many RSLs have been confirmed inside of Valles Marineris, especially in Melas and Coprates Chasmata [5,6]. Chojnacki et al. 2016 [5] propose the possible existence of shallow (10-100 m depth) subsurface water reservoir. The walls of the chasmata are promising exposures that may lead to the subsurface water reservoirs; these exposures would provide means to assign subsurface echoes to their actual depths. Thus this study investigated radargrams and assigned prominent subsurface reflectors to the layers exposed on the wall of Coprates Chasma.

Method: We investigated radargrams in Coprates Chasma and assigned apparent radar depths to the actual depths of layer boundaries exposed on the chasma wall. The target region spans from -70°E to -50°E and from 9°S to 18°S. Our preliminary analysis focused on an east portion of Coprates Chasma. Radargrams were generated from the SHARAD data. The observation frequency of SHARAD is 15–25 MHz, bandwidth of which (10 MHz) corresponds to the depth resolution of 15 m in vacuum [6]. The spatial resolution, based on the synthetic aperture processing, is 0.3 to 1 km along the track direction and 3 to 7 km along the cross-track direction [6]. We identified subsurface echoes and obtained their apparent radar depths (d_{radar}) on a radargram. The actual depths (d) of the identified echoes are calculated by assuming a bulk permittivity (ε_{bulk}=3): $d = d_{radar}/\varepsilon_{bulk}^{1/2}$. The identified echoes were not confirmed using the off-nadir surface reflectors because they were not found in the radargram of surface clutter calculated with MOLA data by applying Kirchhoff approximation.

We described outcrops of the chasma wall using visible images and topographic data. First, layers on outcrops were identified on HiRISE images. Then we assigned those identified layers on CTX digital terrain models (DTMs) with those of orthodox images to determine the actual depths of the subsurface reflectors. The CTX DTMs were generated using MarsSI [7]. In total, we described and generated 11 stratigraphic columns.

Result and Discussion: We identified two subsurface echoes on radargrams in the east portion of Coprates Chasma (Figure 1). Using ε_{bulk}=3, the average actual depths in this region are 32.8 m and 51.8 m for echo1 and echo2, respectively. Echo2 was identified in a limited region around -57°E, -13°N (Fig.2). Using

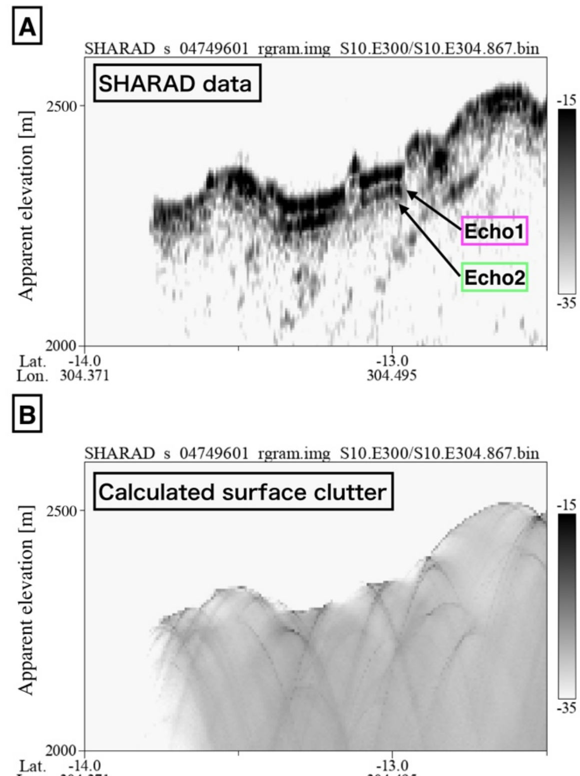

Figure 1 An example of (A) a SHARAD radargram and (B) a calculated surface clutter echo in Coprates Chasma. No apparent clutter echoes appear beneath the surface.

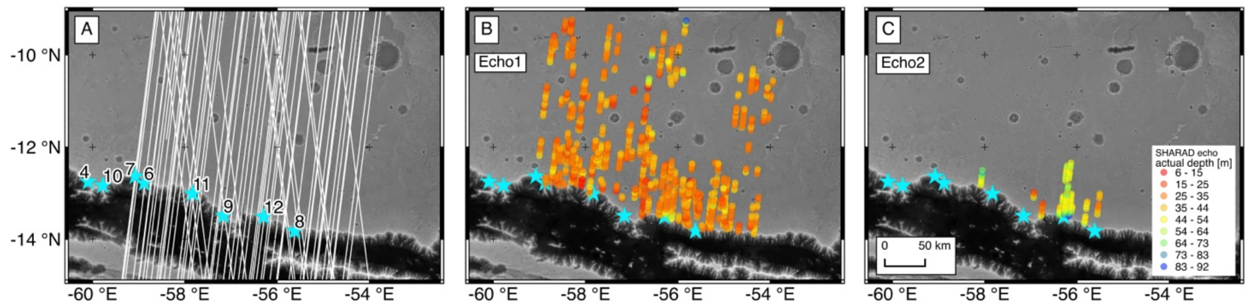

Figure 2 (A) Geospatial distribution and (B,C) actual depth of subsurface radar echoes identified on SHARAD radargrams in the east portion of Coprates Chasma using ε_{bulk}=3. White lines and blue stars indicate SHARAD observation lines and investigated outcrops, respectively.

HiRISE images of the walls, we distinguished very coarse layers that include 15 m diameter of boulders beneath the surface layers with fine substrate (Figure 3A,B). The boundary between the top fine layer and the subsurface coarser layer might correspond to echo1. For example, at point 8 (Figure 2A), the thickness of the topmost fine layer (25.7 m) is identical within the uncertainty to the calculated thickness of echo1at ε_{bulk}=3 (23.6 m) (Figure 3C). In case of echo2, thickness of the subsurface coarse layer obtained by CTX DTMs (9.4 m) corresponds to calculated thickness using higher ε_{bulk} (Fig.3D). The consistency between the calculated thickness from echo1 and the actual thickness at the outcrop validates our assumption of the bulk permittivity and the reconstructed subsurface structure for the upper most layer of the eastern Coprates Chasma. The estimated electric permittivity (ε_{bulk}=3 for the topmost fine layer and ε_{bulk}>4 for the coarse subsurface layer) suggests that the coarse subsurface layer (Figure 3A,B) would represent a higher porosity regolith or contain pore ice. The latter supports the wet hypothesis for the RSL formation that requires the subsurface water/ice source. Further investigations considering the seasonal dependence and the geospatial distribution will clarify the relationship between underground structure and RSLs.

References:

[1] Dundas et al. (2018) *Science, 359,* 199–201.
[2] Stillman et al. (2016) *Icarus, 265,* 125–138.
[3] Putzig et al. (2017) *Icarus, 308,* 138–147.
[4] Orosei et al. (2018) *Science, 361,* 490–493.
[5] Chojnacki et al. (2016) *JGR, 121,* 1204–1231.
[6] Seu et al. (2004) *PSS*, *52*, 157–166.
[7] Quantin-Nataf et al. (2018) *PSS, 150*,157–170.

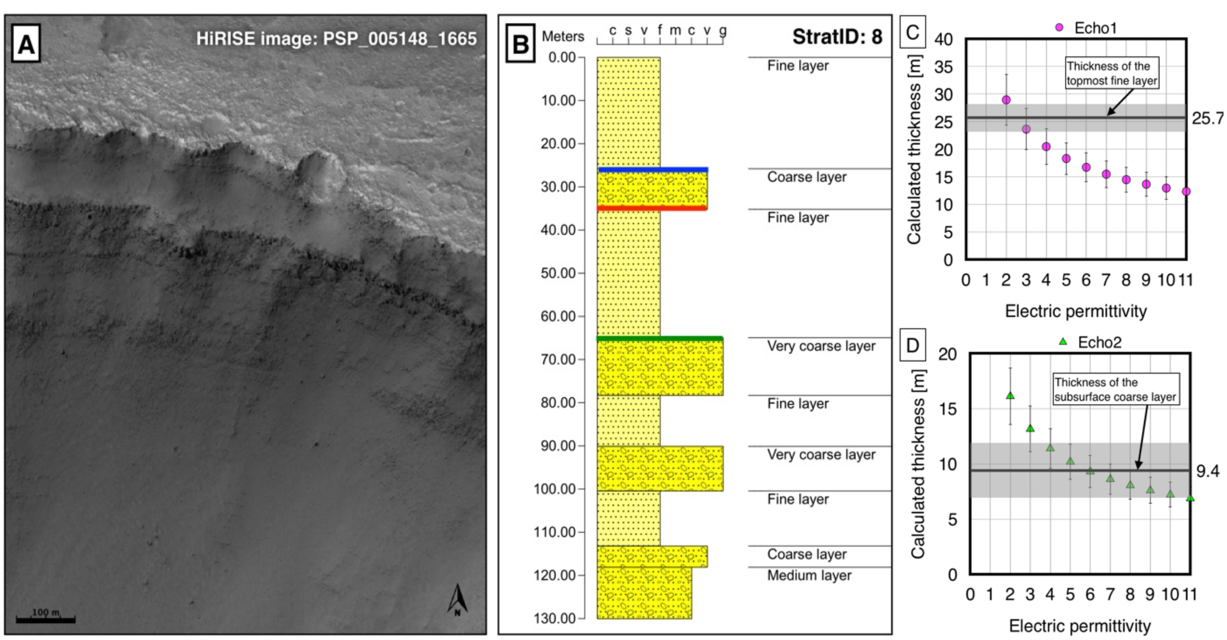

Figure 3 (B) Stratigraphic column and (C,D) an estimation of the electronic permittivity based on SHARAD echo depths and identification on an outcrop (point 8). The corresponding HiRISE image and the stratigraphic column are shown in (A). The correspond SHARAD ID is s_04749601.